MAPS

A GUIDE TO PRACTICAL GEOGRAPHY

By

R. N. DUBEY, M.A., D.LITT.
Allahabad University

ALLAHABAD
KITAB-MAHAL

By the same Author

1. Physical Basis of Geography
2. Economic and Commercial Geography
3. Economic Geography of India
4. Ganges-Jumna Doab
5. Hindustan (Hindi and Urdu)
6. Bhugol Sar (Hindi and Urdu)

PRINTED BY J. K. SHARMA AT THE ALLAHABAD LAW JOURNAL PRESS, ALLAHABAD AND PUBLISHED BY KITAB-MAHAL, ALLAHABAD

PREFACE

My experience of teaching Geography at this University leads me to believe that there is nothing that scares the Indian students more than the practical map work. I am convinced that this is due not to any inherent shortcoming in the student himself, but simply to the wrong approach to the subject at the earlier stage of the study. The map is looked upon not as a vehicle for conveying information, but as a piece of cartographic achievement. I am sure that any one who has a clear concept of the meaning of Geography will agree with me that cartographic art lies outside the domain of Geography in the same way as Mathematics, Physics or Economics, even though we make use of the discoveries of these sciences. Steers in his 'study of Map Projections' quotes a famous French Geographer, Camille Vallaux as saying "La carte est le document de base indispensable pour la Geographie, et ce ne sont pas des geographes qui la dressent." (The map is an indispensable basic document for Geography, but it is not the geographer who constructs it.) This quotation defines the scope of practical map work, which should be centred on map reading. Success in map reading, however, depends on a thorough grasp of the principles of map making. It is only thus that the student can realise the limitations of maps. But the student should never forget that the fundamental object of his study is map reading, not map making.

Map Projections are an essential part of map making. But a geographer has never to draw them to produce his maps or to read those produced by others. He only makes use of outlines that have already been drawn by expert cartographers. Even when he draws the outlines himself, as in field-sketching, the area covered is so small that it is immaterial as to what projection is used. Yet he needs to know the properties of the map projection used in making the outlines of his map. Without this he cannot read the map correctly. But to know these properties it is not necessary for him to enter into mathematics. He need not trouble himself as to how certain formula used in map projections have been derived. For this reason the subject of map projections has been placed at the end in this book, and has been treated without any mathematics. Only the most commonly used projections have been included.

The book is primarily written for Indian students and, therefore, the illustrative material has been selected from Indian conditions with which they are familiar.

University of Allahabad, R. DUBEY
4-2-1943

CONTENTS

CHAPTER III

INTRODUCTION

A map may be defined as a conventional representation or picture of the earth, or any part of it looked at from above, on a *flat* piece of paper. The representation bears a certain proportion to the area represented. This proportion is the *scale* of the map and is always marked on it.

The mere fact that the earth is round, while its representation is flat which cannot show the earth's curvature, implies that the very basis of all maps is wrong. The absence of a proper appreciation of this error has resulted in the past in our having in mind a wrong picture of the earth. We must remember that only the globe gives us a true picture of the shape of our earth.

The earth is, however, vast. Its surface is greatly varied and full of a variety of details. To take note of all this detail through the printed word in books is not practical. Consider how many pages will be filled if you listed only the moderate-sized towns of the world. You cannot look at all this list at one glance. You will have to spend some minutes before you have read through the whole list. Besides, the towns in your list give you nothing but their bare names. The list cannot give you any idea as to the setting and environment of these towns. It tells you nothing as to the relationship that may be existing between some of the listed towns.

Now, consider the case of all these towns being shown on a flat map which starts from a wrong basis of showing a round earth on a flat paper. In spite of its drawback, you can get a generalised picture of all these towns at one glance, in a few seconds. You can know at once in which part of the earth are there many towns, and in which part few. You can also note at the same time the topographical setting and the relationship of these towns. In short, the map enables you to grasp, at one glance, simultaneously divers details which it is not possible for you to do by any other method. The map, therefore, became, from the start, the chief instrument of the study of Geography. For, it must be remembered, that Geography draws its conclusions about distributions only by considering varied details presented side by side. Not only do the maps present varied data side by side in their proper relationships of distribution, they also help to fix these data more easily in the mind, for they are a kind of picture-reading which is less taxing to the brain than word-reading.

Types of Maps

Maps are of numerous types. Some are for general use; e.g. maps of areas giving data of different kind. Others are for special use, giving data of a particular kind. The example of the latter is the climatic or other distribution maps. Cartographers are generally interested in the first type of maps.

Based on the size of their scale, the general maps are divided into the following types:—

1. *Cadastral maps*, drawn on a very large scale varying from 6 inches to 25 inches or more

to a mile, are used to show estates or towns where the area to be represented can be conveniently covered by one sheet of paper.

2. *Topographical maps*, drawn on a fairly large scale, say from a quarter inch to 4 inches to a mile, represent small areas and give a large amount of detail of a varied nature.
3. *Chorographical maps*, drawn on a small scale, say 32 miles or 64 miles to an inch, represent large units of the world and give the most generalised picture of the area. These are generally the small scale atlas maps of countries.
4. *World maps*, drawn on flat paper to take the place of the globe.

The last two types of maps, the chorographical and the world maps, were in existence even in early times. But the topographical maps are a product of the modern times. These maps are prepared after a careful survey based on triangulation. Modern Europe emerged from a number of wars during the 18th and 19th centuries which required for their success in operations topographical maps giving accurate information. National surveys were, therefore, started by the countries of Europe from 1750 onwards.

France was the leader in these surveys. It was in this country that topographical maps based on accurate triangulation were made and published first. Cæsar Francois Cassini (1714-1784), a descendant of a famous family of cartographers of France, was the first to do this work. He started the 'Carte Geometrique de la France' in 1747 on a scale of 1/86,400 which was com-

pleted after his death by his son in 1789.

The Carte Geometrique was later followed by another series of topographical maps, Carte d'Etat Major on the scale of 1/256,000 prepared by Napoleon's engineers. In this series were included, besides France, parts of Italy, Germany and Austria.

Great Britain was not far behind France in topographical mapping. Ordnance Survey was founded in 1791 and triangulation was begun by General Roy. The first topographical map of Great Britain was published on a scale of 1/63,360 in 1801.

The Geographical Section of the General Staff (G. S. G. S.) of the British Army has produced topographical maps of areas outside Great Britain, as well. Among these the maps of Asia and Africa are of special note.

Under an impetus from the British army the Survey of India was started about the beginning of the last century to produce topographical maps of India. The Survey has produced maps not only of India, but also of the adjacent countries.

The topographical maps that were produced by the different countries of the world followed their own scheme and scales, so that there was no coordination of any kind. The need for a common scheme and a common scale was, therefore, greatly felt. An event of great cartographical importance, therefore, took place when the International Geographical Congress of 1891, held at Berne, decided in favour of such an international topographical map of the world on a scale of 1/1,000,000 (known as the 'millionth map'). Little was, however, done until 1909 when the British Govern-

ment called a meeting of the principal governments of the world. A common scheme was decided upon and every government was allotted a particular area which it was to map. India and Great Britain are the only countries which have completed their allotted task. The 1/M map produced by the Survey of India is known as the 'India and Adjacent Countries' series. The sheets in this series are 4×4 degrees and have contour lines, altitude tints and shading.

The other countries are making this map in sheets as given below:—

Upto 60° of latitude the separate sheets are to include 4° of latitude and 6° of longitude.

Beyond 60° upto the pole the sheets are of 12° longitude and 4° latitude; i.e. two sheets of the above size are to be united into one.

CHAPTER I

MAP MAKING

As the map is a conventional *picture* of the earth, it is implied that the person who draws this picture must have *seen* the earth or *guessed* rightly what it looks like. In other words, the data for the map must be collected by *survey* or interpolation. Surveying and interpolation are, therefore, the first steps in making a map.

FIELD SURVEY

Surveying consists in determining the relative *positions* of the various objects on the ground, so that they can be shown on the map in the same relationship. In order to fix this relative position of objects, it is necessary to take some measurements. These measurements are of the *directions* in which the objects are situated and the *distances* at which they are situated from one another. No survey is useful unless both these measurements are carried out. Measurement is, therefore, the essence of field survey. The greater is the care taken in measurements, the more accurate is the survey. A careful measurement, however, takes time and requires more labour. This will entail a much greater cost than if less time is given to measurements and survey. In actual practice it is noticed that maps are required for various purposes. Some purposes

require very elaborate and carefully-prepared maps. In such cases the survey has to be very carefully done. There are, however, other purposes for which even less carefully prepared maps will do. In such cases, a very careful and accurate survey, costing much money, is a sheer waste and uneconomical.

Survey work is, therefore, classified under two heads:—

(i) Traversing, or a less careful work; and
(ii) Triangulation, or an elaborate work.

TRAVERSING

Traversing consists in surveying quickly a narrow strip along a road or a route, observing only the most prominent objects visible clearly from the road or the route followed by the surveyor. In some cases it is practicable only to make a few notes of the observations outdoor by the surveyor. In such cases the notes are made in a note book, called the Field Book. Plottings are made later from these notes. The field book is ruled according to the requirements of each surveyor, but generally it has a central column in which the data concerning the actual route or the path followed are given. To the right and to the left of this column the data are given concerning objects situated to the right or the left of the path respectively. The data in the central column consist of:—

(i) the direction in which lies the next point to which the surveyor is heading on the road. This is the most distant point on the path that is visible from the starting point. The measurement of this direction

is expressed as a 'BEARING', of the compass. This bearing is given in degrees of angle read from the dial when the compass is sighted on that distant point.

(ii) Distance. The distances between the various intermediate points, as also the total distance between the starting point and the last point sighted from there are given. The total distance is written vertically in order to distinguish it from the intermediate distances.

As the surveyor moves along, he makes observations about objects to the right or the left of the path. These are entered on the appropriate side of the central column in the field book. Such observations give:—

(i) Offset distances to nearby prominent objects. The offset distances are always measured from a point on the path just opposite, i.e. at right angles, to that object. It is not necessary, therefore, to take a bearing for that object.

(ii) Bearings of objects which are situated at some distance and whose measurements cannot be obtained easily.

Besides the data mentioned above, names and any additional useful information about the objects observed are also noted at the appropriate place in the field book.

Fig. 1 shows the specimen of a field book.

Note that the entries in the field book are made from the bottom of the page upward and from the last page backward. That is to say, if there are ten pages in the book, the first entry will be made at the bottom

of the tenth page and when that page is filled the next entry will be made at the bottom of the 9th page and so on.

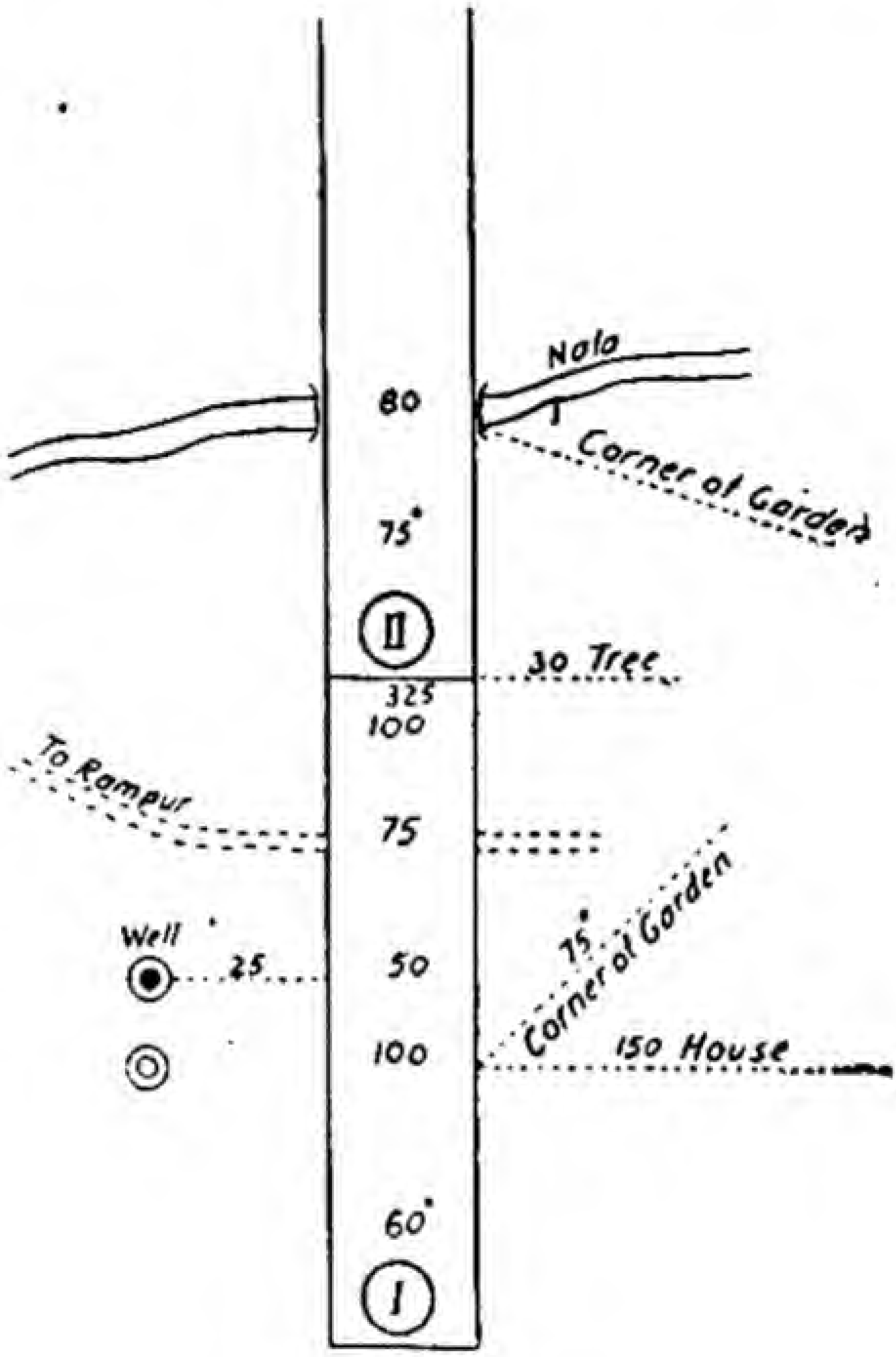


Fig. 1

The stations are marked in their serial order and put in a circle. The distance separating one station from the other is called a '*leg of the traverse*'.

Conventional signs are often used to mark the objects observed.

The data in the field book are later plotted on a paper. The plottings are done with the help of a protractor for measuring the angles and a ruler for drawing the lines. The first angle giving the direction from the

starting point of the traverse is measured and a direction line is drawn. From this direction line the distances are measured and the objects marked by their signs. Any other detail regarding the traverse is transferred from the field book to the paper on which the plottings are being made. This gives us the map which is later elaborated and finished by the draughtsman in the printing press.

Adjustment of Error

Plotting often reveals that the observations of bearings given in the field book have not been correctly made. This is found out by the last plotted point not tallying with the actual position of the object in the field. Where the exact position of the last object is

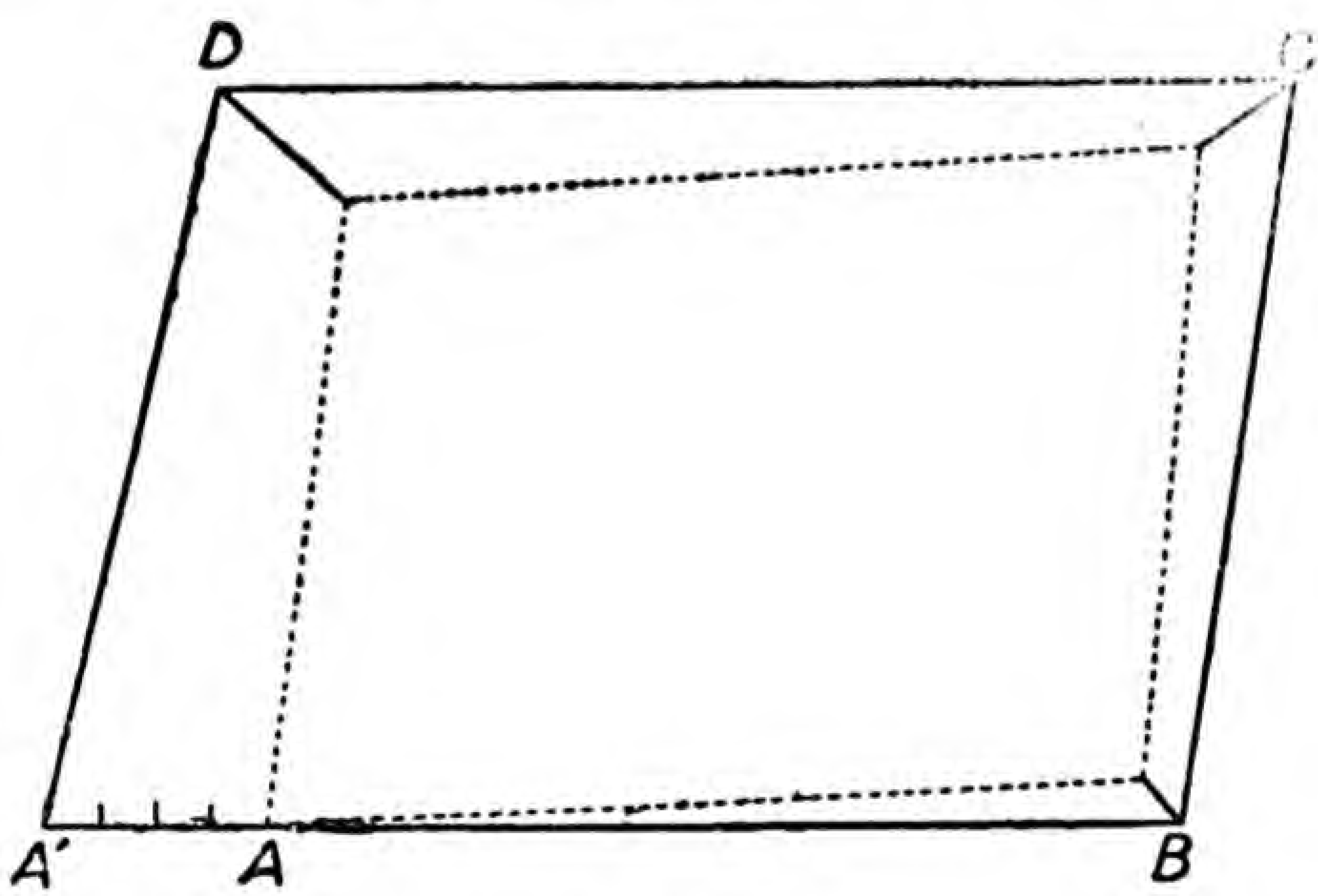


Fig. 2

known, the error is distributed and dotted lines are drawn alongside the original lines to show the correct

path of the traverse. Where the traverse is *'closed traverse'*; that is to say, where the surveyor comes back to the same point from which he started, this error can be easily determined; for in such a case the last plotted point must coincide with the first point. In Fig. 2, it is shown how the error is adjusted.

The traverse started from A (fig. 2) and finished there. In plotting also, therefore, A and A′ should coincide. The plotting, however, results in the figure ABCDA′. That is to say, A and A′ are not coinciding. To adjust this error A is joined to A′ and the line AA′ is divided into four equal parts, as there are four legs to the traverse. A small diagonal line is drawn to the left of B, C, and D in such a way that at B it is equal to one part, at C to two parts and at D to three parts. A dotted line then joins these new positions of the points B, C and D represented at the end of the diagonals. The figure given by the dotted line shows the correct traverse.

Plottings in the Field

Sometimes no fieldbook is prepared, but the observations are plotted, directly as they are taken, on the paper. This gives more satisfactory results.

Instruments for Traverse

All the usual instruments for survey, e.g. the Prismatic Compass, the Plane Table, the Chain or the Theodolite can be used for traversing. The theodolite is, however, seldom used for this purpose as it is comparatively unwieldy.

The most common instrument for traversing is the

Prismatic Compass. It is an ordinary magnetic compass provided with three special adjustments. These are:—

(1) A prism, to enable the reading of the bearing straight without bending over the compass or shifting the position of the compass itself.

(2) A sight vane with a thin wire which is directed to the objects which are under observation.

Fig. 3

(3) A magnetic dial, instead of the usual needle. On this dial are engraved the graduated readings from 0 to 360. This dial moves to show the new bearing as soon as the compass is moved this way or that way.

For making observations the prismatic compass is:—

(i) mounted on the tripod stand;

(ii) put in a level plane by adjusting the legs of the stand, so that the liquid in the spirit level fixed on the compass is in the middle;

(iii) the prism and the sight vane lifted straight.

Now, stand on the side of the prism, put one finger on the stop-button under the sight vane, and look at the object through a small hole on the prism-side by fixing one eye to it while closing the other eye. You are looking now at the object through the sight vane and also at the graduated readings of the dial on the inner side of the compass under the sight vane. In order to get the bearing, you must steady the magnetic dial by pressing the stop-button just for a while.

The advantages of the prismatic compass for traversing are:—

1. It is portable and, therefore, can be easily taken from one place to the other, even in a difficult country;

2. It is suited for quick work, specially in a flat, forested country where there are no prominent landmarks.

Its disadvantages for this work are:—

1. It is expensive, costing about two hundred rupees, especially when compared with the plane table which costs about fifty rupees only.

2. The accuracy of its observations is generally impaired due to the magnetic effect. The magnetic dial is attracted towards the magnetic objects and does not, therefore, give the correct bearing of the object sighted.

Because of this defect it cannot be used near iron. Bridges, railway lines, iron poles etc., cannot be used,

therefore, as observation points.

PLANE TABLE

The Plane Table is a kind of ordinary drawing board mounted on a detachable tripod. It is fixed to the tripod by means of a screw on top of the tripod. When this screw is tightened the table is fixed. To revolve the table, however, in any direction the screw is loosened. The size of the table varies, but usually it is small, about 10″ by 15″.

Besides the table top, there are two other accessories of the plane table which must be regarded as essential parts. These are the ALIDADE (it is also called the sight-rule), and the BOX COMPASS (also called Trough Compass). The alidade is a flat graduated ruler at the two ends of which are fixed two sights. Sometimes these are flap sights which can be lowered flat on the ruler when out of use. One of the sights has holes, while the other has a long slit through which passes a hair or a thin wire. In order to use the alidade the surveyor puts his eye to the sight that has a hole and looks at the object through the slit in the other sight. It is necessary that the hair or the thin wire in the slit should be supposed to cut the object sighted. In order that there should be no errors in sighting, the line joining the sights at the two ends of the ruler must pass through its centre. Sometimes, for very accurate work in place of the sights at the end of the ruler, the alidade has a telescope mounted on its centre.

The box or trough compass is a rectangular box covered with a glass lid. It contains a magnetic needle moving on a pivot to show the magnetic north. The

chief use of the box-compass is to draw two parallel north-south lines enclosing the box so that the table might be properly 'set' with their help at any place.

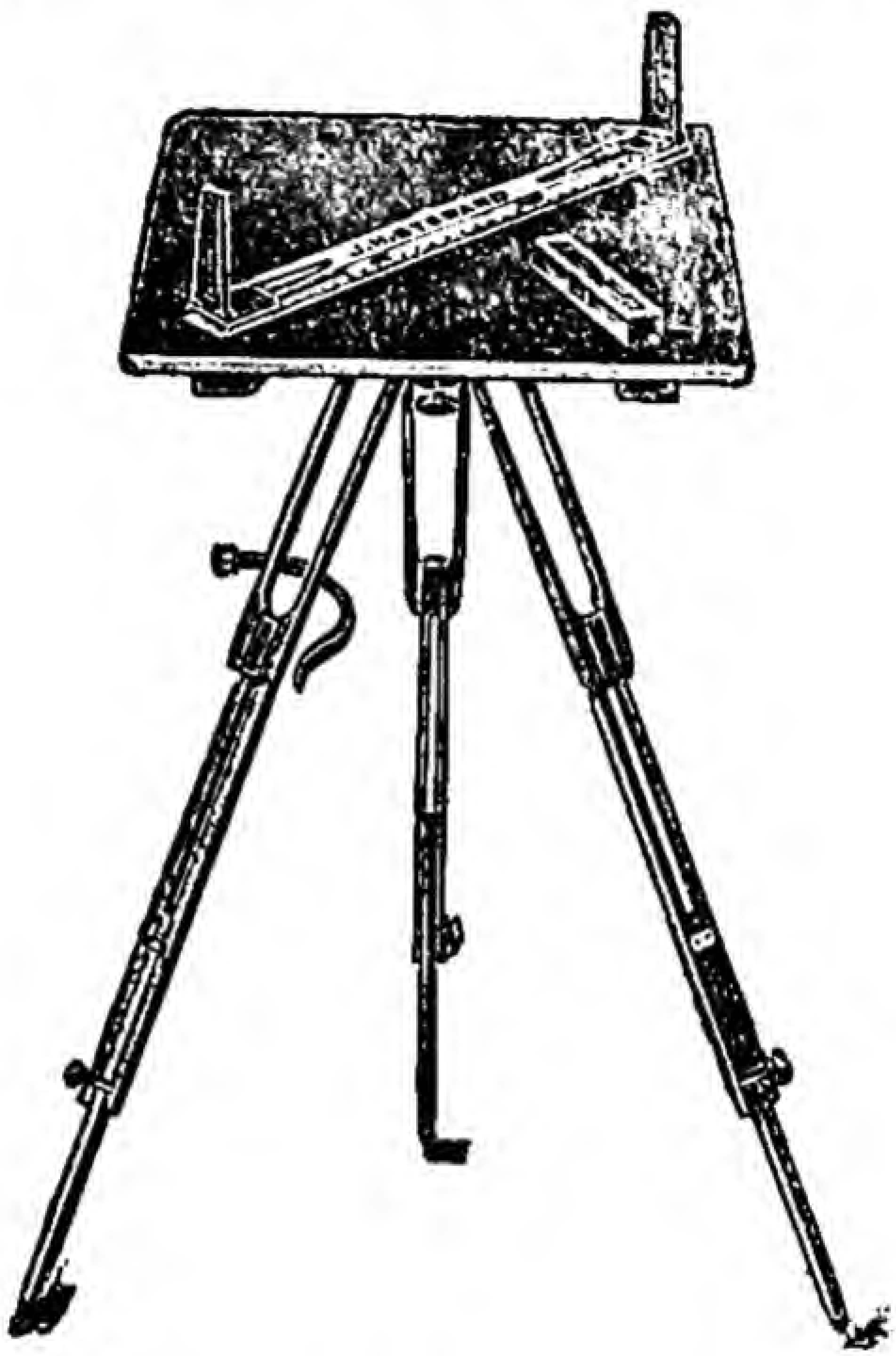


Fig. 4

A tape for measuring distances and a spirit level for levelling the table are also necessary with the plane table.

Chain

The chain (often called Gunter Chain) consists of 100 links or iron rings linked together. To facilitate counting, every tenth link is marked by a brass tag. The

total length of the chain is twenty-two yards. Its use is confined to making boundary surveys of small fields.

CHAIN TRAVERSE

The chain traverse is the simplest traverse and often consists of closed traverse. The chain is held on the ground in a straight line near the boundary of the field. Offsets are measured from this line, before removing the chain, to the boundary in order to bring out its real shape. The chain should be placed as near the boundary as possible. This is done with a view to have only short offsets which can be measured quickly and accurately. Long offsets are always inconvenient for this purpose. While laying the chain on the ground, it is necessary to guide the man carrying the other end of the chain, so that he remains as near in a straight line as possible, close to the boundary. The measurements are re-

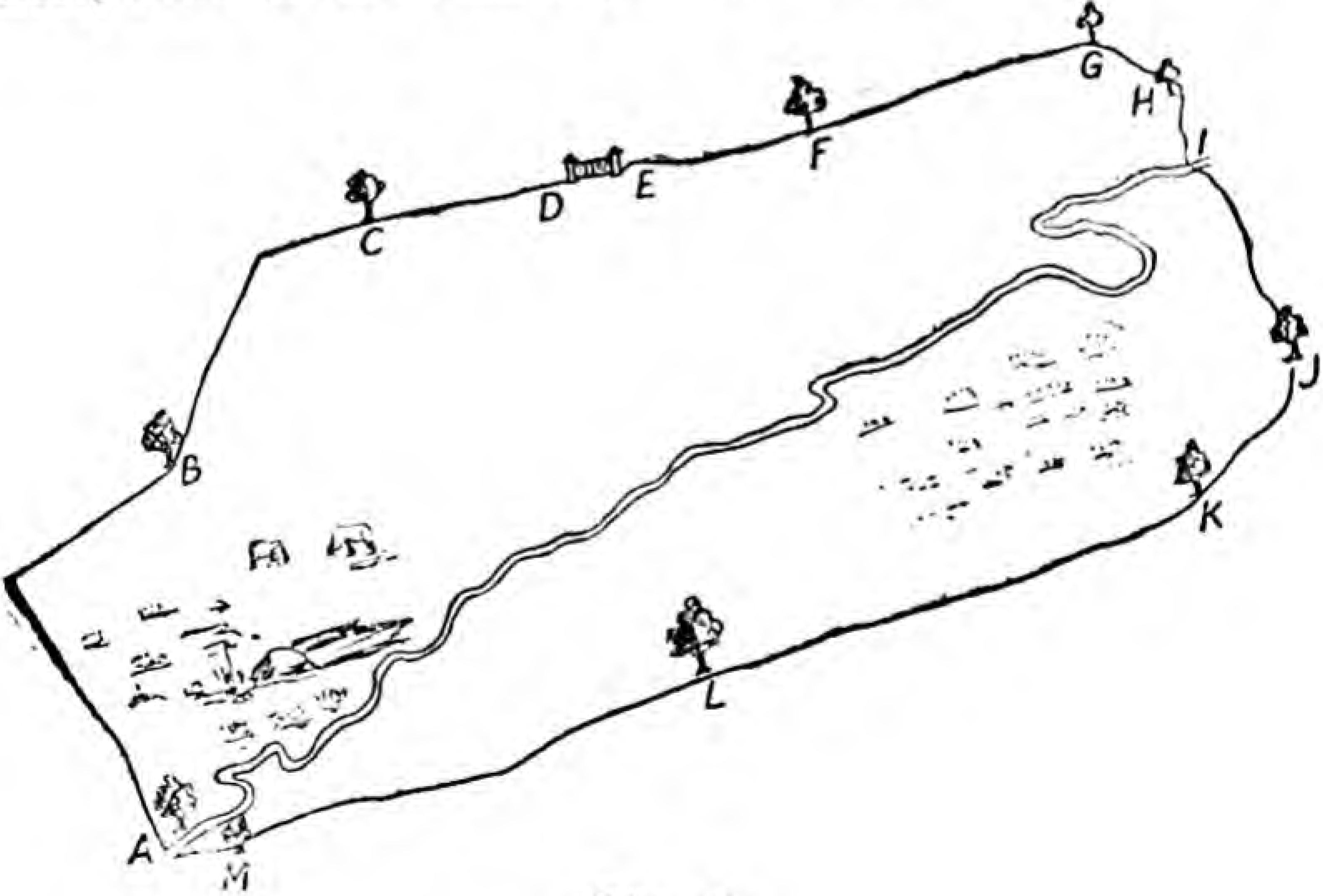


Fig. 5

corded in a field book from which plottings are later made. The field book is almost similar to the one used in a compass traverse.

Suppose we have to make a chain traverse of the field shown in Fig. 5.

We go round the field once and observe the prominent features that we shall use as ruling points. The Nala, the trees and the gate are the most prominent objects for this purpose.

We start from the tree marked A on the Nala, we lay the chain on the ground along the boundary in a

Offsets	Links	Stations
	600	M
10....	570	
	500	L
	400	K
	370	J
5....	350	
	300	I
	290	H
10....	280	
	270	G
	250	F
10....	220	
	200	E
	180	D
	140	C
10......	120	
5....	90	
	70	B
15......	50	
5....	10	
	0	A

Fig. 6

straight line. We mark the position of the starting point by a nail and holding one end of the chain close to it direct the man holding the other end to move to his right or left in order to be in a straight line from the starting point. He then marks the position of his end by another nail or peg. This peg will be the next point from which the chain will be spread onward towards the point B. When the second peg has been struck we measure the offsets from the chain to the boundary. All these measurements are entered into the field book which is as in Fig. 6.

The diagonals AC, AG and AJ may be measured separately to help in plotting. When plotted the field will appear as follows:—

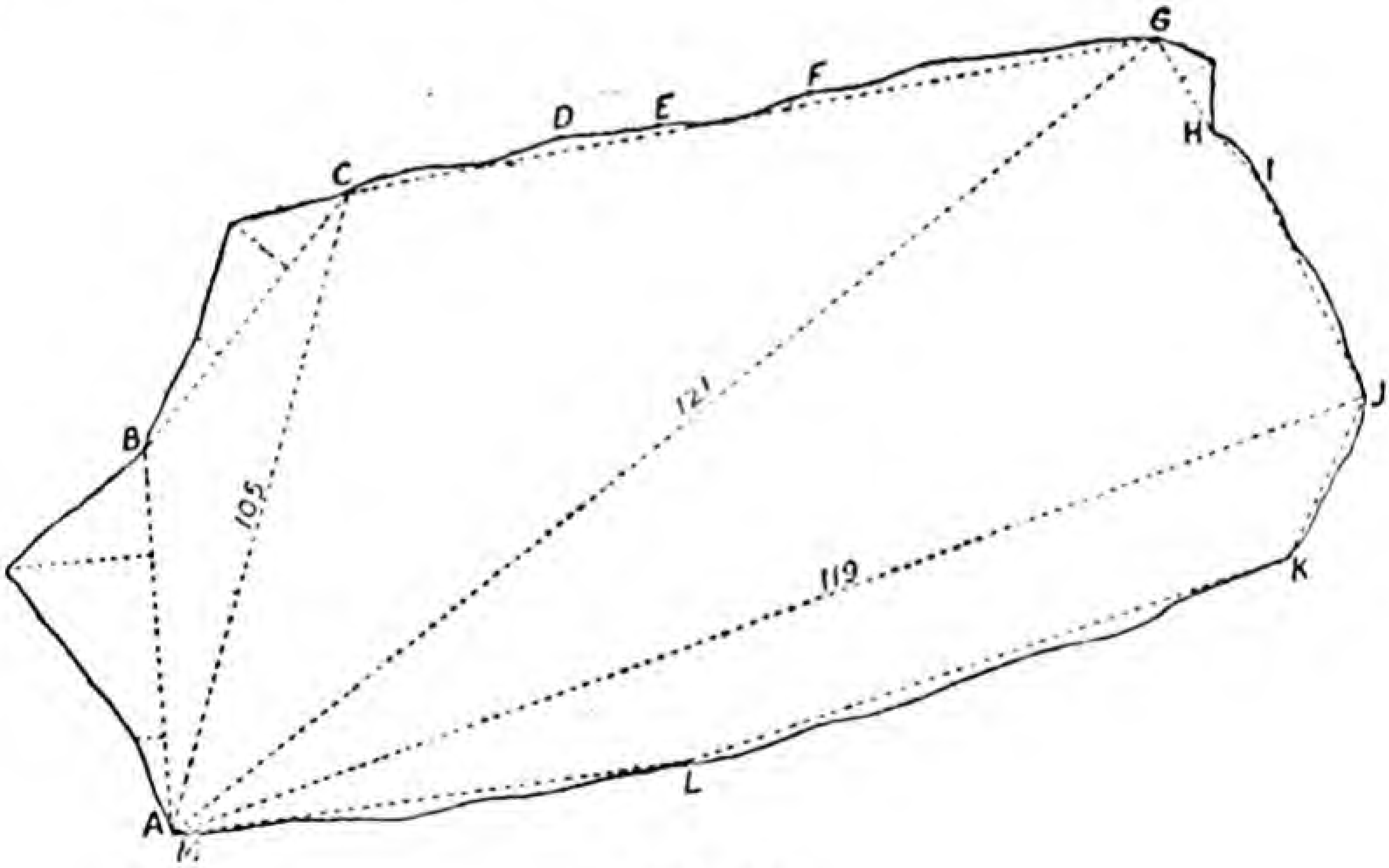


Fig. 7

The dotted lines in the above diagram show the chain lines while the regular line shows the boundary.

Triangulation

The object of triangulation is *area-survey* rather than *route-survey*. For this purpose the field of operation is divided into a number of triangles. This gives the word 'triangulation'. The essence of triangulation lies in *measuring the base line of a triangle* and thus fixing two of the points of that triangle. The third point of the triangle is fixed by intersection of the *direction lines* drawn from the two ends of the baseline. It will be noted that the only measurement involved in this kind of survey is the measurement of the base. All other measurements are deduced by the simple rules of trignometry. As the points of the triangles are fixed by observation from two points they are accurately fixed. Thus, less measuring and greater accuracy are the outstanding features of surveying by triangulation. This method of surveying, however, implies a more detailed observation and, therefore, it is necessarily slow. In military parlance triangulation is called 'position-sketching'.

Triangulation is of two kinds:—

(*a*) Theodolite Triangulation;

(*b*) Graphic Triangulation, or the triangulation done with a plane table.

Theodolite Triangulation

The theodolite is an elaborate but very expensive instrument. Its chief feature is that it can measure more accurately the angles formed by objects sighted than is possible with the help of a prismatic compass. Because of this accuracy larger areas are first divided into tri-

angles with the help of the theodolite and the details within the triangles so formed are later filled in with the help of the plane table. The points of these triangles

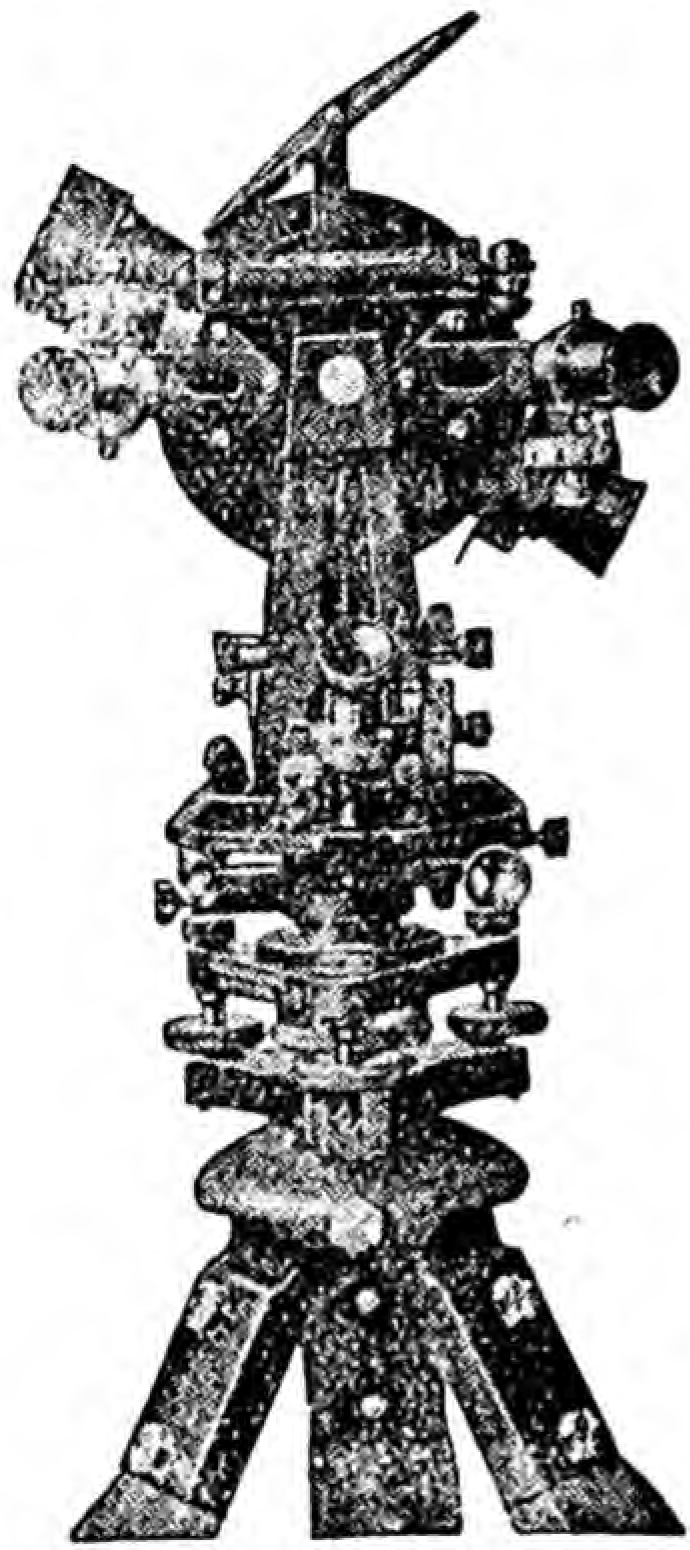


Fig. 8

are marked by permanent masonry structures and are known, as *trigonometrical stations*.

Before an area is triangulated, a preliminary survey for ruling points is carried out. Then a base is fixed and triangulation proceeded with by forming new triangles from each of the points fixed. This process is continued

until the whole of the area has been triangulated. In order to check the accuracy of the work a *check base* is measured in another part of the area and this measured length is compared with the length given by computation from the triangles. Theodolite triangulation really speaking consists in *fixing the base, extending it and checking it*. This importance of the base requires that the the surveyor should pay particular attention in selecting it. The baseline should:—

(i) Be *central* to the area, as far as possible;
(ii) Be on a *level* ground;
(iii) Give a *clear* view of the country around;
(iv) Give sight of a few prominent *landmarks*;
(v) Be about a mile in length.
(vi) Be measured several times very carefully and then the average taken.

Similar care should be given to the selection of the ruling points. These points should be so selected that the angles formed by them with the baseline should be as near right angles as practicable. Objects forming too obtuse or too acute angles should be avoided. Theodolite triangulation is shown below:—

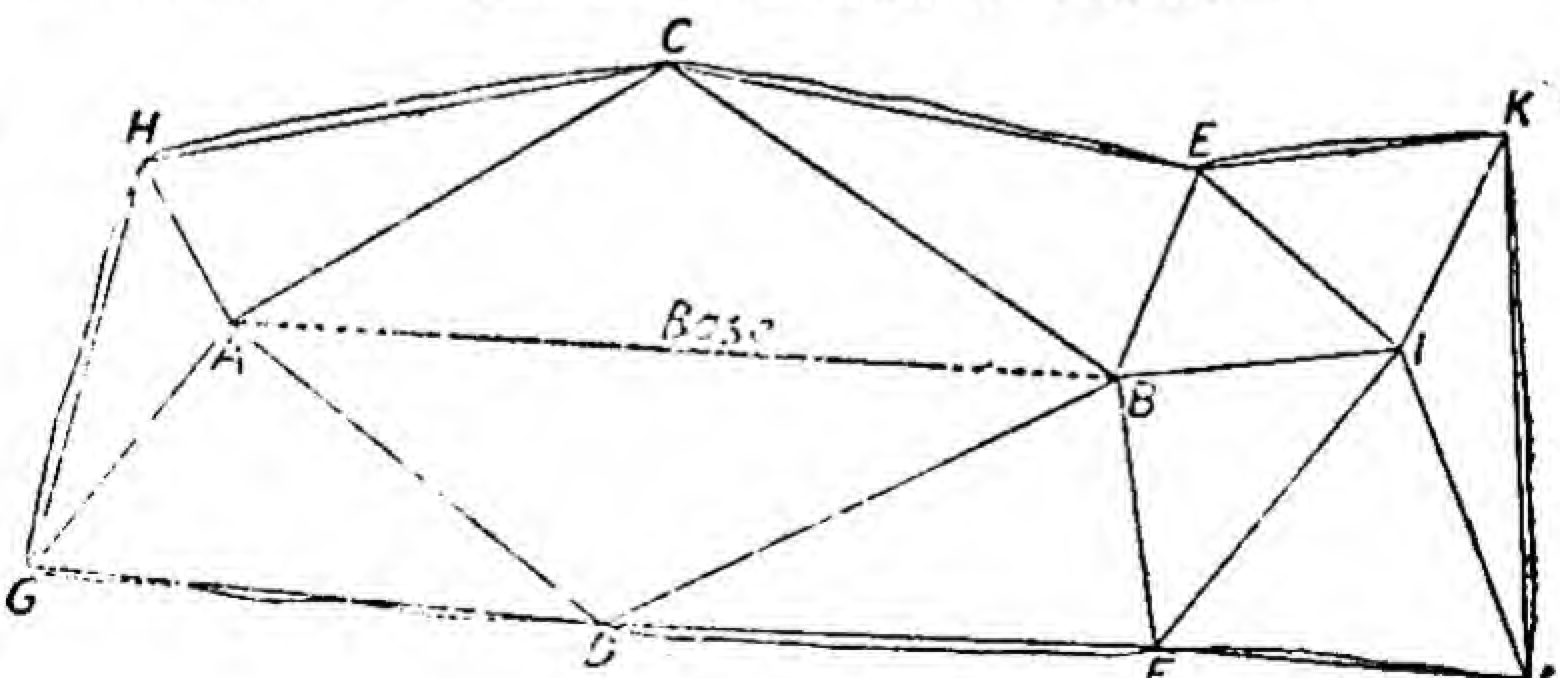


Fig. 9

In the figure above A, B, C etc. are the points of the triangles fixed by triangulation. The dotted line shows the extension of the baseline.

The preliminary survey of the area leads the surveyor to select the prominent objects marked by the letters A, B, C, D etc. The base is then selected and measured. With the help of the theodolite it is then extended to A and B which are objects situated several miles apart in the same straight line. From A the theodolite is sighted on B and then at C and the readings noted. These readings determine the angle CAB. The theodolite is then taken to B. From there it is sighted on A and C respectively and the angle ABC is thus fixed. Then it is shifted to C and by the same process the angle ABC is fixed. The side CA is now taken as a base and the point H is fixed. Similarly the side CB is considered as a base for fixing E. By continuing this process of taking the sides of the already fixed triangles as base new triangles are fixed. The triangulation is thus completed.

When the details are filled in by the plane tabler, these points are used by him, and it is not necessary for him to measure a baseline.

Graphic Triangulation

When the plane table is used to make a framework of the area as well as to fill the detail of the area surveyed, the survey is described as 'graphic triangulation'. In such a case the first thing is to fix carefully a base line. All the points given in connection with the baseline under theodolite triangulation apply to the baseline in graphic triangulation as well. In length, however, it

is shorter to suit the convenience of the plane tabler. Once the baseline has been fixed the other points are easily located. One special advantage of surveying by the plane table is that once the table has been set, the directions are measured easily and accurately merely by aligning the alidade on the ruling points. As in the case of the theodolite triangulation, points already fixed help the fixing of other points. It has been noted above that in the theodolite triangulation the baseline is measured and then the angles are measured. In graphic triangulation, however, the only measurement involved is the measurement of the baseline. All other measurements can be found out by computation.

The process of graphic triangulation implies first the mounting of the paper on the table. For it must be remembered that all plottings in graphic triangulation are done directly from observations in the field. The paper should, therefore, be fixed in such a way that it does not move, even slightly, during the course of operations. The best method of fixing the paper is to pin its edges under the top of the table so that there are no pin-heads on the table-top to obstruct the free movement of the alidade. A more satisfactory method is to wet a piece of thin cloth and place it on the table, smoothing the creases. On top of this cloth the paper is then placed. The edges are, as before, pinned under the top. This method gives a smoother surface of the paper and the drawing of lines becomes very easy.

To start operation, first select the two conspicuous points which will form the ends of the baseline. Place the table near one end of the baseline and then level it, that is to say, place its top in a horizontal plane. For

this purpose help is often taken from a spirit level. Draw the North line with the help of the compass. When the table has been put in a level and the North line drawn it is said to be 'set'.

Now, mark a point on the paper to represent the position of the table. Put this point in a circle so that it is not lost. Then loosen the screw holding the table-top to the stand. This is called 'unclamping' the table. Place the alidade alongside the point and revolve the table until the object at the other end of the base can be sighted through the sight vane of the alidade. Now, tighten the screw under the table top. This is called 'clamping' the table. Then draw a line along the edge of the alidade in the direction of the object sighted. This line is the BASE LINE. The line representing the 'Base' is usually a thick line.

Having drawn the Base Line, the alidade should be pointed to other prominent objects visible from the position of the table and *direction lines* drawn. These direction lines are called '*rays*'. For drawing the rays the alidade is pivoted at the point representing the end of the Base Line and shifted to the right or the left to bring it opposite to the object to be sighted. It must be remembered that throughout these operations the table remains fixed. It is only the alidade that is moved.

When the rays have been drawn from the first point of the Base to all the objects desired to be fixed, the table is shifted to the other end of the 'Base Line' carefully measuring the distance. Before doing this a peg is left at the first end to mark the position of the table.

At the other end of the Base Line the table is placed and the top put in level as before. It is then un-

clamped and revolved with the alidade lying alongside the Base Line already drawn. The alidade is pointed at the object at the first end of the Base. When this object has been got through the sight vane the table is clamped by tightening the screw. The table is now said to be ORIENTED. The orientation of the table, thus, means the placing of the table in such a way that the two objects marking the two ends of the Base are in one straight line.

When the table has been oriented, the length of the Base is marked on the Base Line by a point which fixes on paper the position of the second object. For this purpose a suitable scale for representing distances has to be adopted. The measurement of the Base and its representation, the Base Line, on paper should be very carefully done, as this will form the basis of all computations to be made for finding the distances between various objects in the field.

Rays are then drawn from the second point of the Base to all objects to which they were drawn from the first point. This is done on the same principle as in the case of the rays from the first point; i.e. by pivoting the alidade on the point and moving it right or left to get the objects into the sight vane one by one. These second rays will intersect the first rays at a certain point. This point of intersection fixes the position of the object sighted.

If necessary, rays to new objects not visible from the first point of the Base, may also be drawn. These rays may be utilised later from other points.

The frame-work is thus provided. Now, rub out all the unnecessary lines leaving only the Base Line and

the intersections of rays. Topographical details may then be shown. Rivers, roads, trees etc. may be sketched with the help of the positions of the objects already fixed in the frame-work. The figs. given here (10, 11 and 12) show how the paper on the table will look as the operations described above are completed.

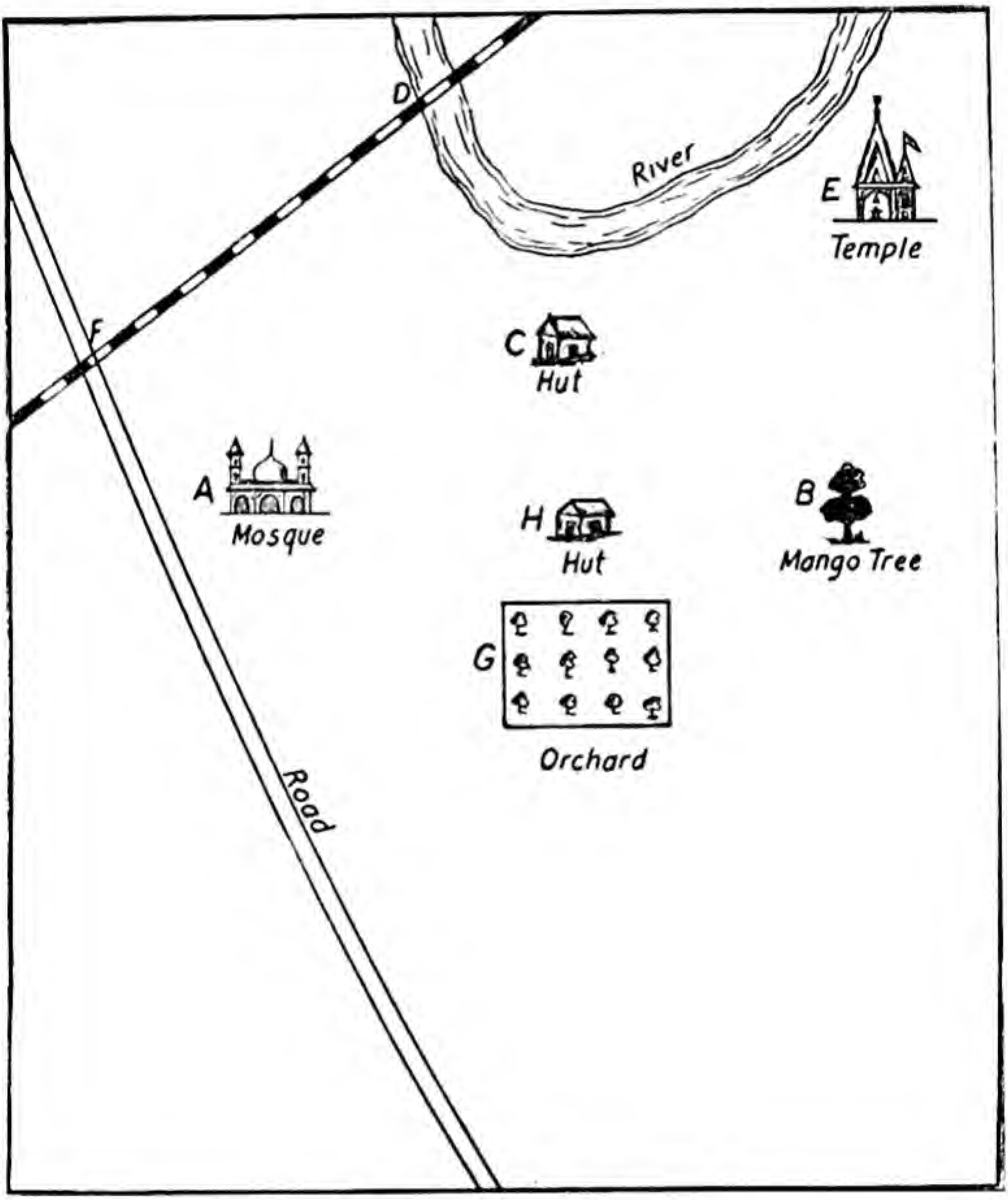


Fig. 10

The above field (Fig. 10) is to be surveyed by Plane Table. A preliminary survey will reveal the various prominent features shown in the diagram. It is clear that the mosque and the mango tree can very well form the two ends of the Base marked A and B. The table is placed near the mosque and a direction line is drawn towards the mango tree. Rays from A are then drawn to the hut (C), railway bridge on the river (D), Temple near the river (E), Level crossing (F), the corners of the orchard (G and H) and the other hut (I). These operations will appear on the paper as follows:—

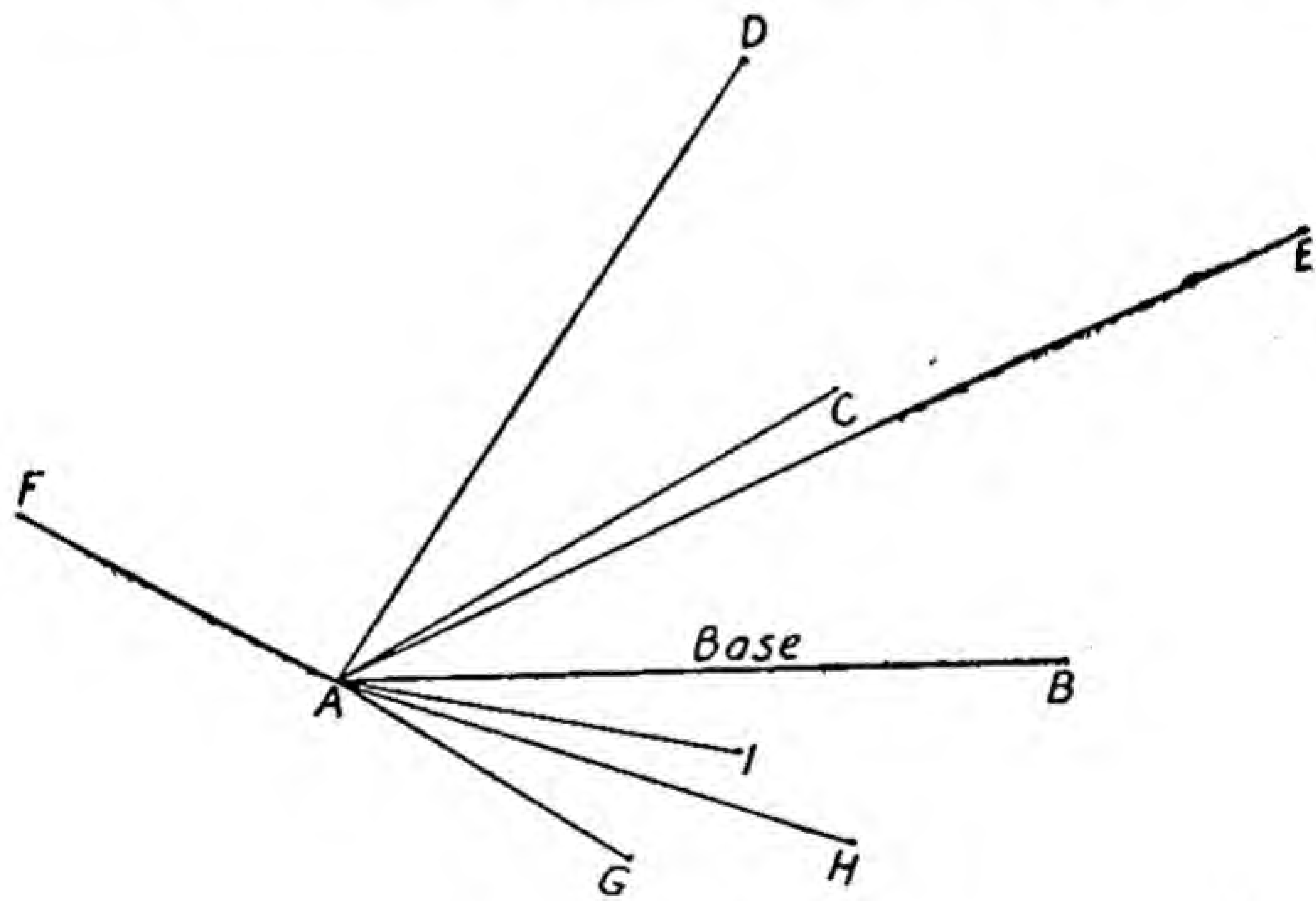


Fig. 11

The table will then be shifted to the mango tree and oriented. The point B will then be fixed by plotting the measurement of the distance between A and B. Rays will then be drawn from B to all the objects

to which they were drawn from A. These operations will appear as follows:—

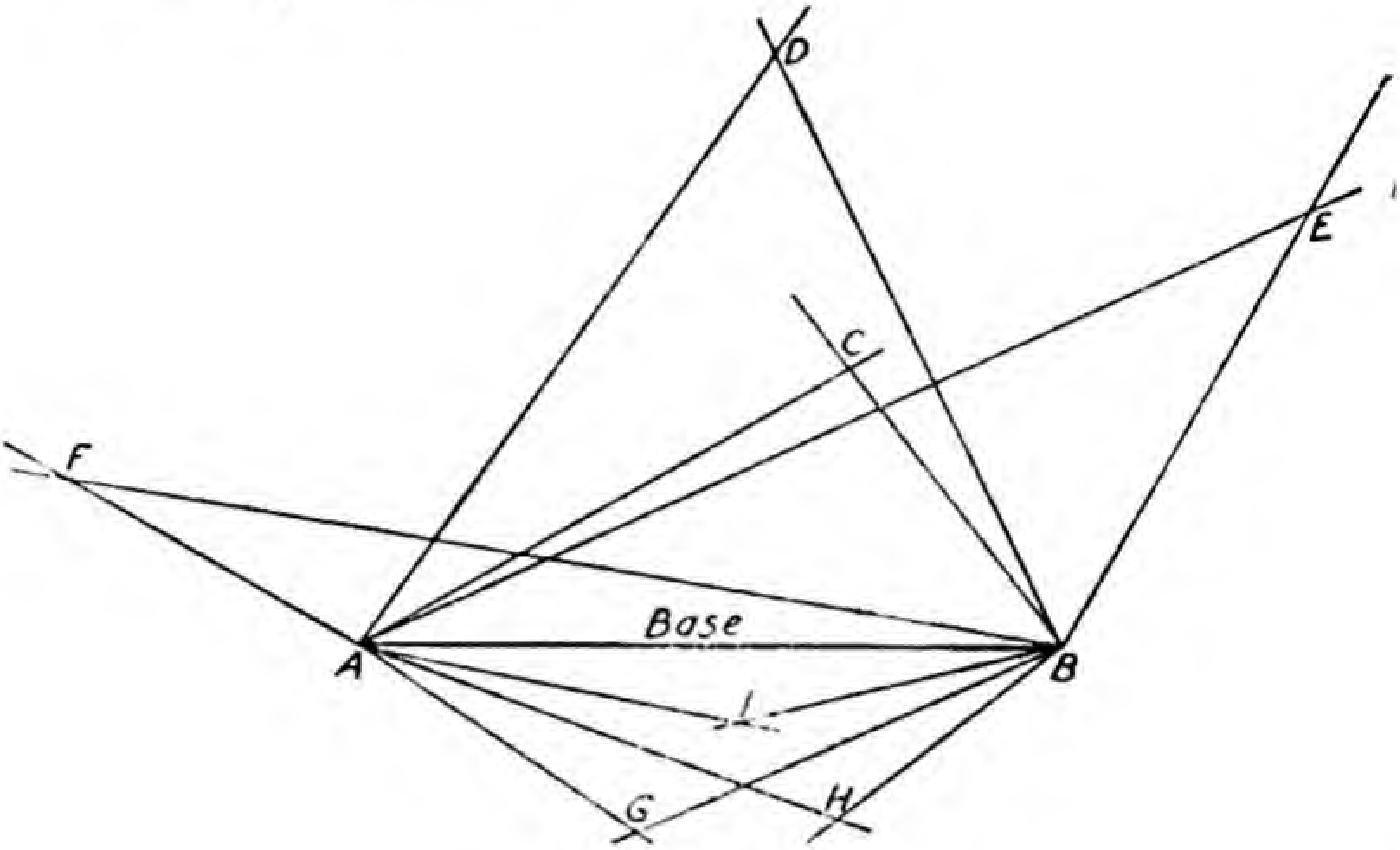


Fig. 12

The superfluous lines will then be rubbed out leaving only the Base Line and the intersections. Topographical details will then be sketched in.

Resection

Resection is the method for determining one's position on the Map. It describes the process of fixing the position by referring to previously fixed points without actually going to them. For this purpose the map is placed on the top of a plane-table and set. Some familiar objects in the field which are shown in the map are then sighted in such a way that the line of sight passes through the representations of those objects in the map. Rays are then drawn on the map

backward from the object sighted to the position of the table. Where these rays intersect, that is the position of the table in the map. To get good results it is better to select at least three objects situated in three different directions in the field.

The following diagram shows this process. Dotted lines show the back rays:—

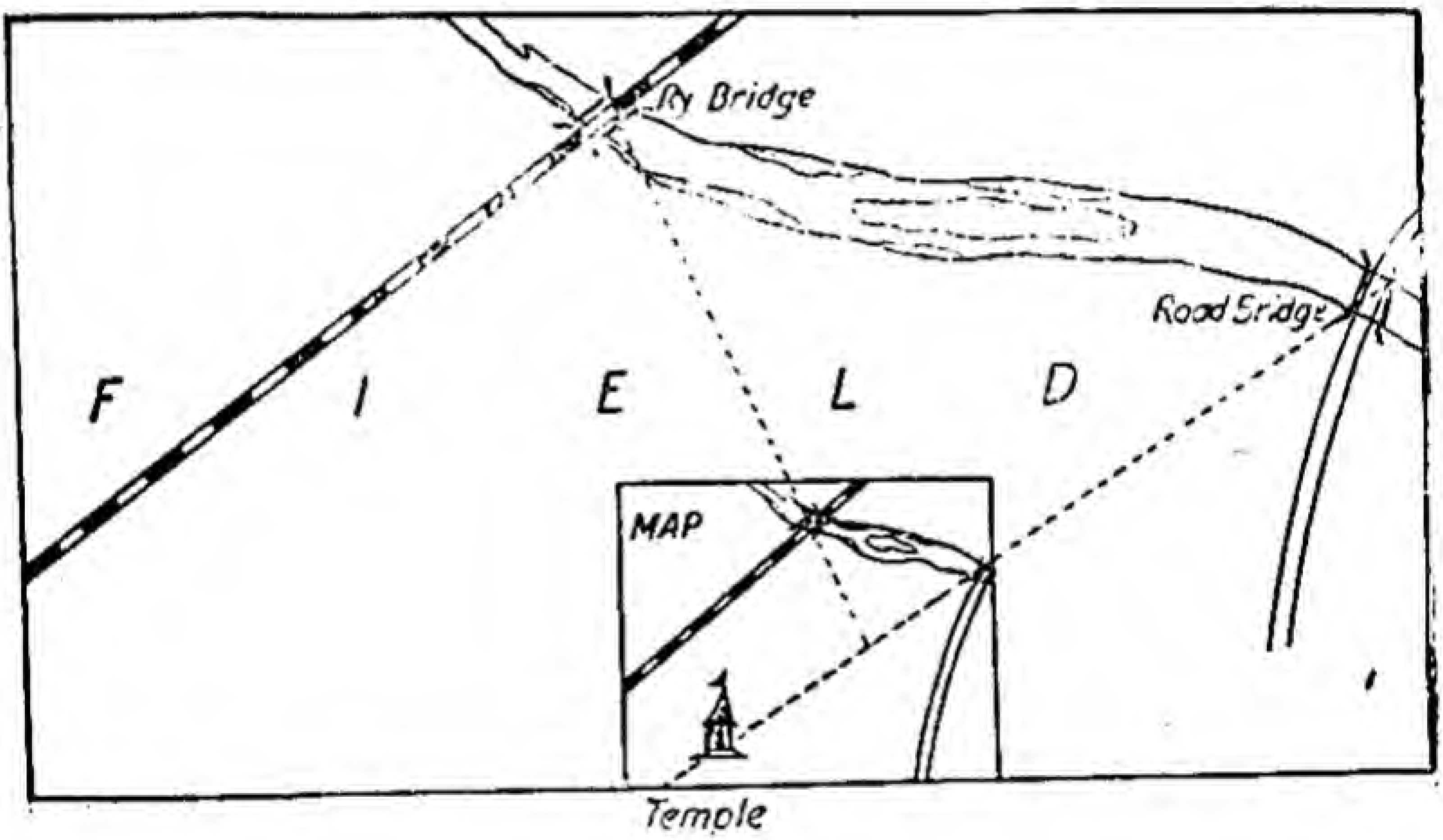


Fig. 13

Very often, due to defective laying of the table, the rays do not meet in one point. They form a triangle. This triangle is called the '*triangle of error*'. The table has then to be shifted to the right or the left and the rays are drawn again before they intersect in a point.

The shifting of the table is done according to some rules. These rules are as follows:—

(i) If the table stands within the triangle made by the objects in the field, its position on

the map will be *within* the triangle of error. If it stands outside, the position will be *outside* the triangle of error.

(ii) If the position is outside the triangle of error, it can only be either to the right or to the left of the triangle of error.

(iii) The position will be nearer to that side of the triangle of error which is formed by the shortest ray, and farthest from that made by the longest ray. In other words, the perpendicular lines drawn from the position to the rays bear the same propor-

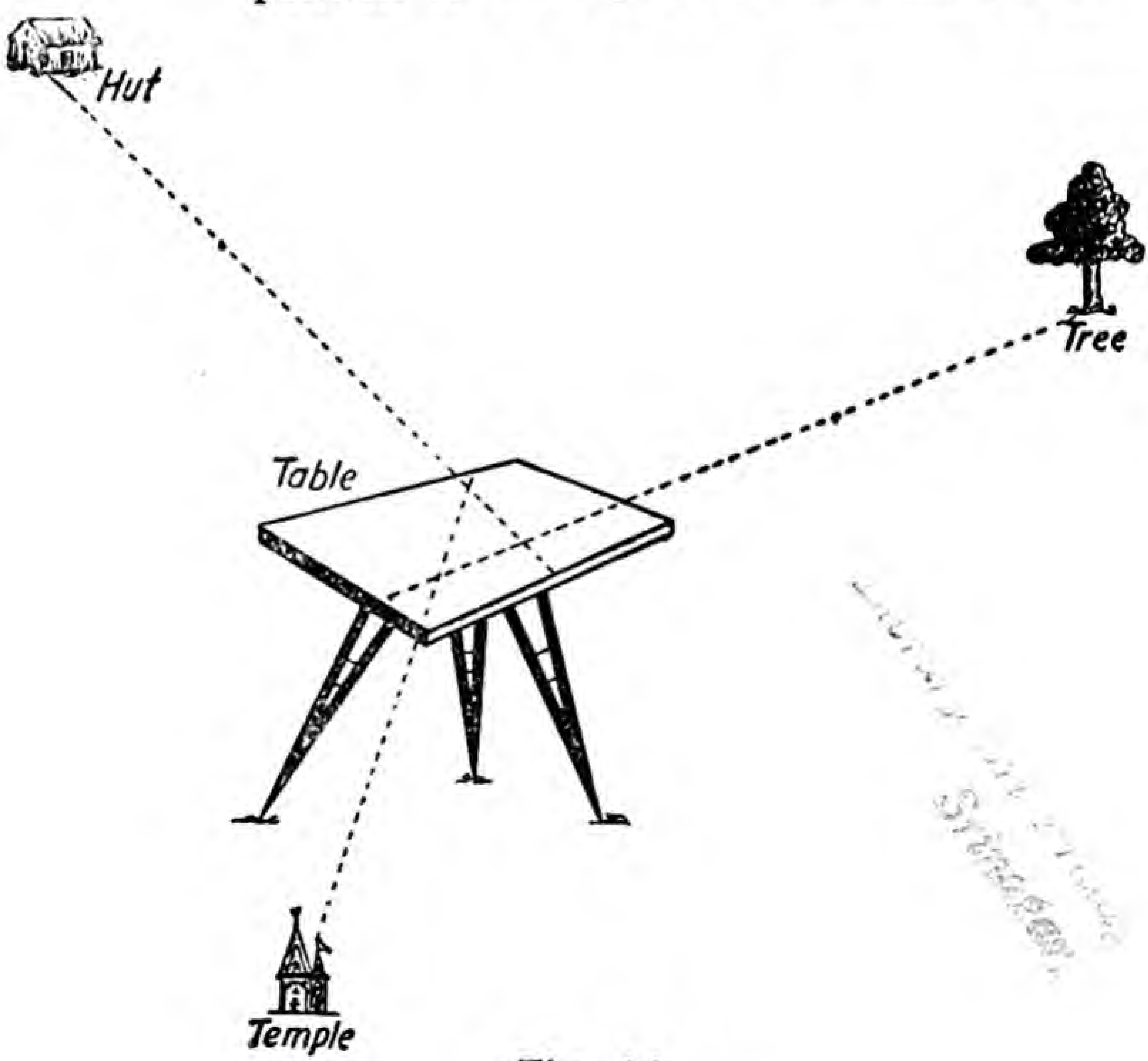


Fig. 14

tion as the distance separating it from the objects. In short, shift towards the ray from the nearest object.

In order to decide whether the position is to the right or the left of the triangle of error, the table is to be shifted to the right or the left and rays drawn again. If the resulting triangle is smaller the position is to the side to which the table was shifted If the triangle is larger, the position must be on the opposite side.

In Fig. 14, the position is within the triangle of error, while in Fig. 15 the position is outside the triangle.

Resection fails to fix the position of the table when

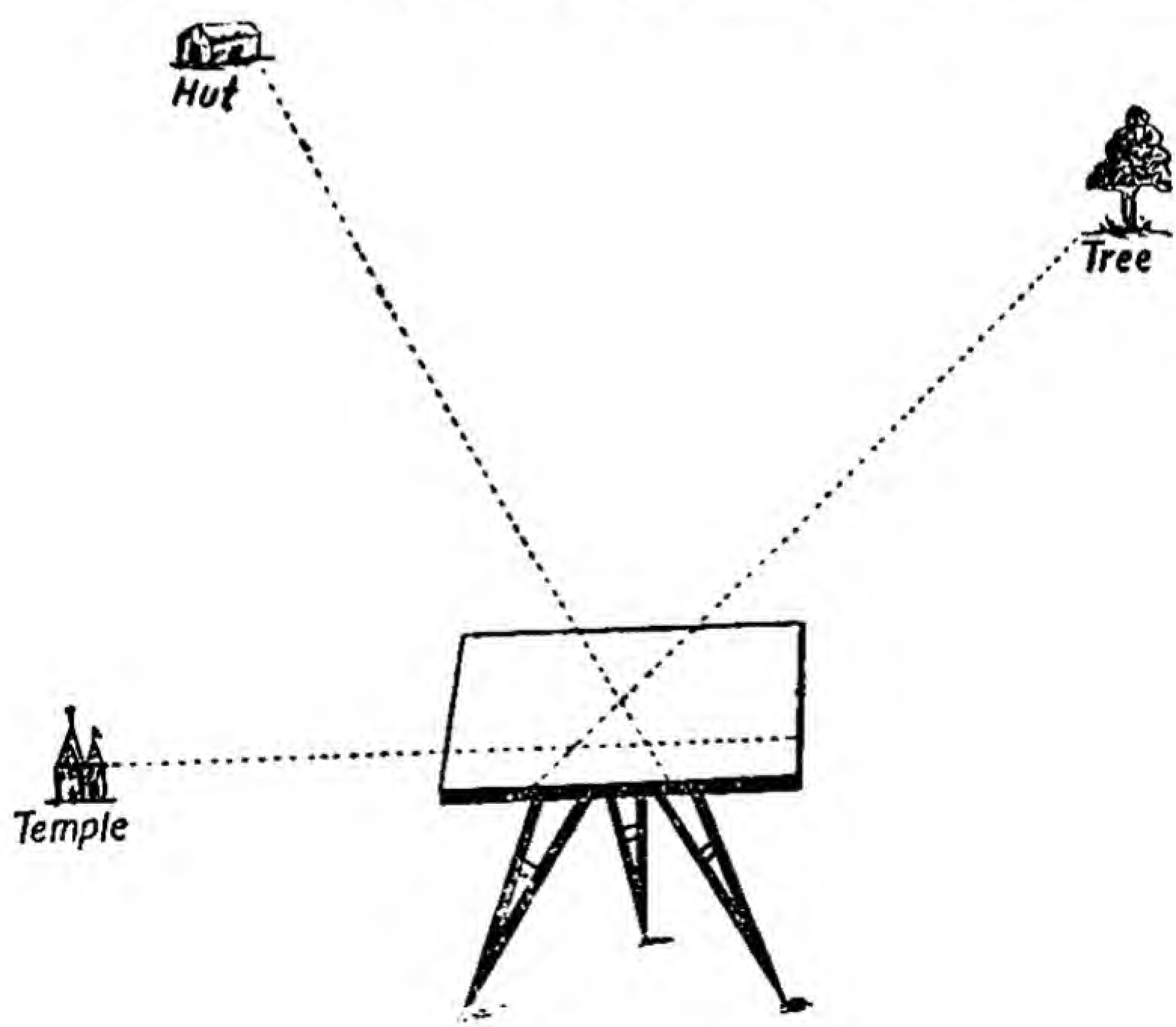


Fig. 15

it is on the circumference passing through the objects selected for drawing rays. Such objects should, therefore, be avoided, for they are in the 'danger circle'.

Tracing Paper Method

Position on the map is also sometimes determined by the tracing paper method. For this purpose take a piece of tracing paper, place it on the table and tack it. A point, say D, is selected in the centre of the tracing paper. Rays are then drawn from this point in the direction of three objects visible in the field. After this the tracing paper is untacked and is moved around over the map until these three rays pass through the three corresponding points for the objects on the map. There is only one position of the tracing paper which will satisfy this condition, and the central point, D will thus give the position of the table on the map.

The table should be oriented then by placing the alidade on any one of the three rays and the corresponding object in the field sighted.

Contouring

While the frame-work of an area is being completed with the help of a plane-table or a prismatic compass, heights of objects above sea level and the general slope of the ground are also marked in the map. This latter process is called '*contouring*.' For this purpose, a clear idea of the drainage lines and the main ridge lines is necessary.

To facilitate contouring two things are essential in the frame-work being prepared. The first is the marking of the rivers, and the second, the location and

the observation of elevation (known as spot height) of certain selected objects in the field. The marking of the river and the location of the object is done in the ordinary course of the survey. The observation of the spot height is done by various means. If the surveyor is on the spot, i.e. on the top of the elevation the height may be observed by the use of a barometer. The barometer records decreasing air pressure with increasing height above sea level. The normal air pressure at sea level being known, the height can be deduced by a simple arithmetical calculation.

The following gives the figure of a spring barometer or the 'aneroid':—

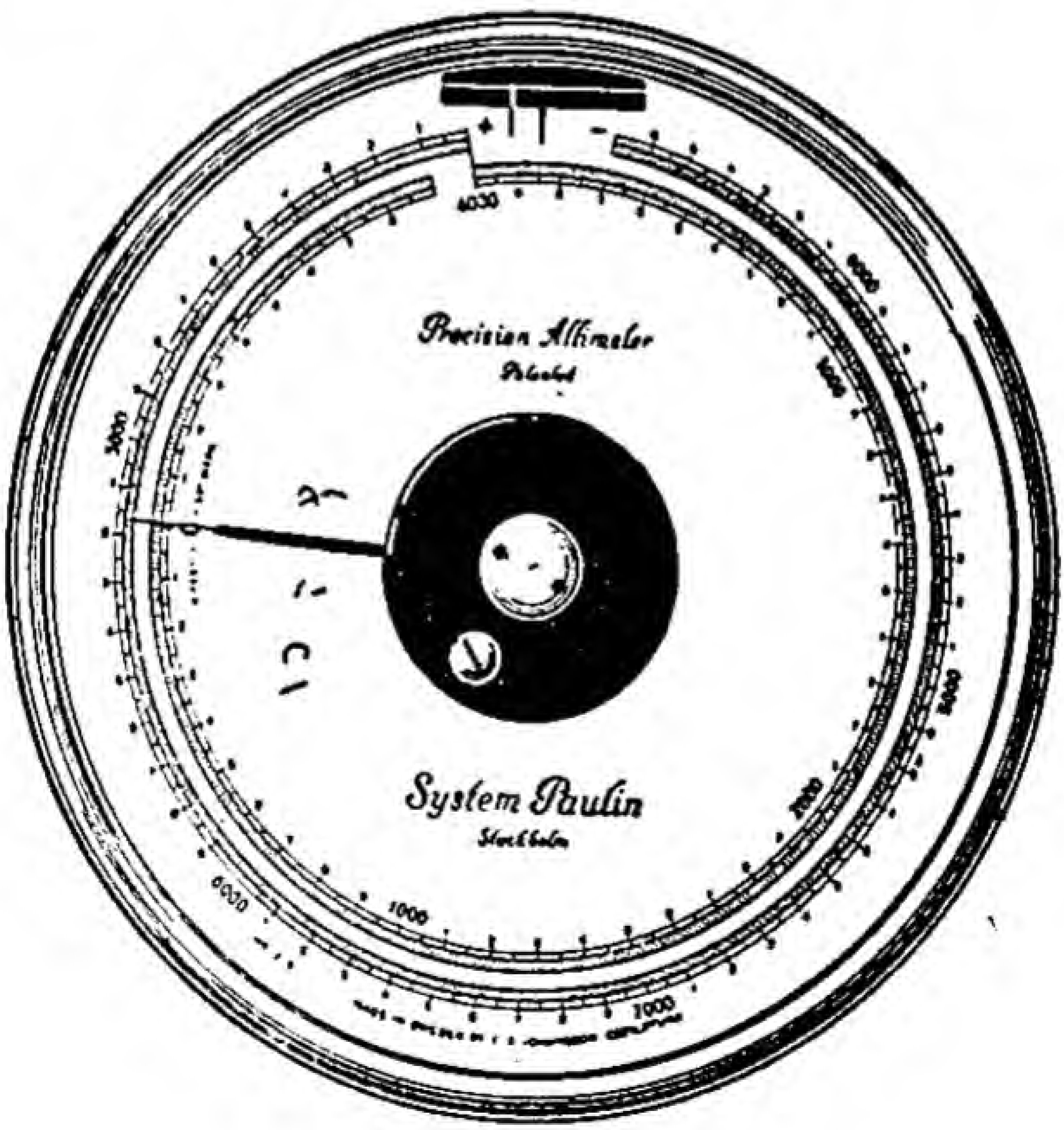


Fig. 16

The height is also found with the help of another instrument called the 'Level'. The Abney Level is in common use. The Level measures the verticle angle, and with the help of this angle and the horizontal distance separating the observer from the object the height is deduced.

The vertical angle can also be measured by another instrument called 'the Clinometer.' The Indian Clinometer is the cheapest and the most common in use.

From the spot heights and the general impression of the slope of the ground contours are interpolated. First of all the contour interval (or the V. I.) is decided upon. Then the places where the contours will cross the river are marked. To mark the places where the contours will cross the river, it is necessary to select a portion of the river where the slope is uniform and the view unobstructed for some distance. The length of this stretch of the river is then estimated by the eye and divided by the contour interval. These divisions mark on the map the points where the contour lines will cross the river.

In the following plan (Fig. 17) the spot heights and the rivers in a certain area are shown and the contour lines are to be interpolated:—

In the diagram A marks the lowest point on the main river. B, another point situated on the same river, is separated from A by a uniform slope. If the contour interval of 50′ is adopted, A and B will be the points through which the contour lines of 50′ and 100′ respectively will pass.

The ground between the river forks is always a ridge. We notice from the heights given in the dia-

gram (fig. 17) that these ridges are provided here by the hilly ground to the right and left of all the rivers in

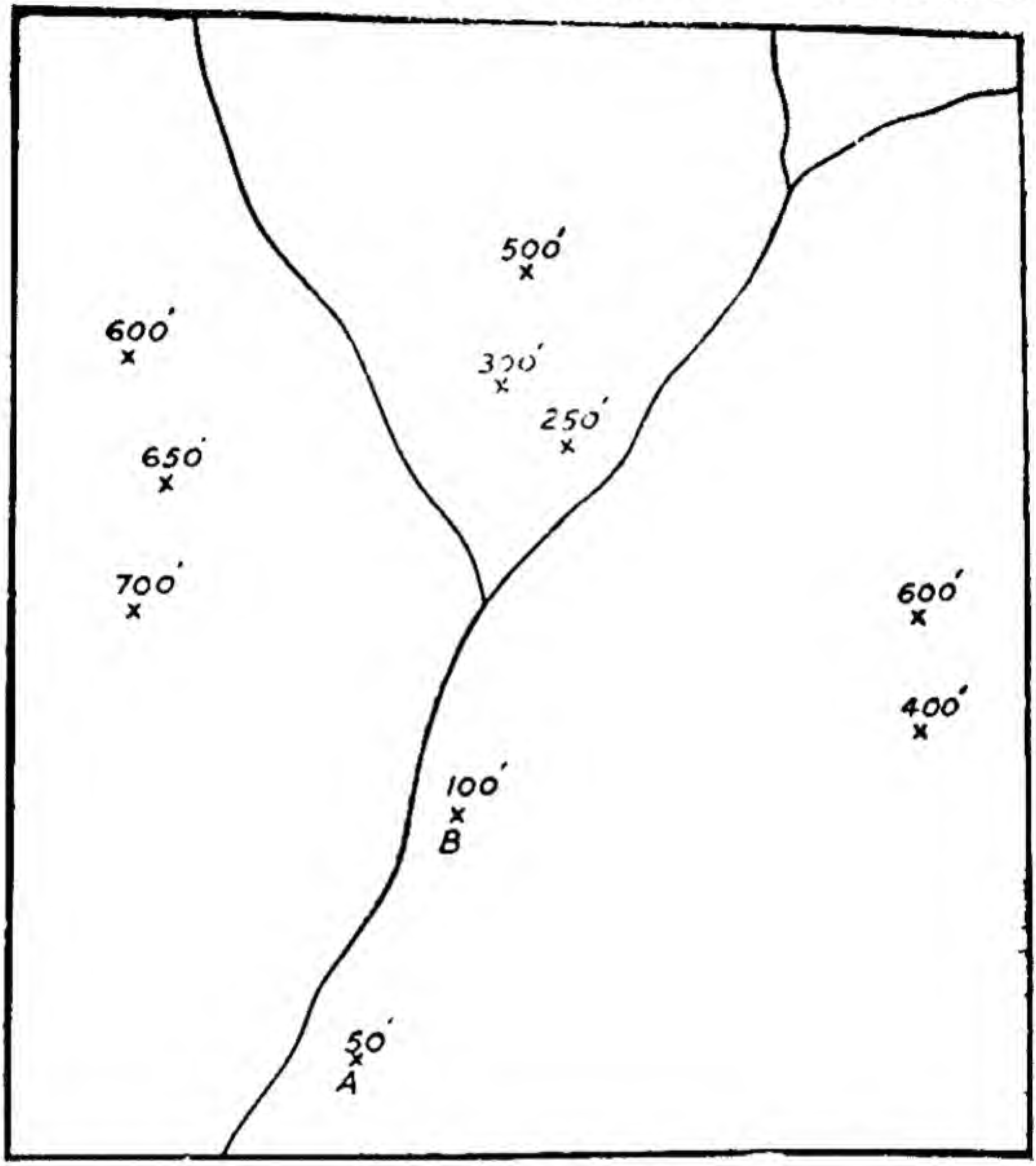


Fig. 17

the upper course. The observer in the field will be able to notice the exact direction of the slope and the hills. It is necessary to remember in this connection that *contour lines bend upward in the river valleys and downward in spurs* or hill slopes.

The above sketch may, therefore, have the contours something like those given in Fig. 18.

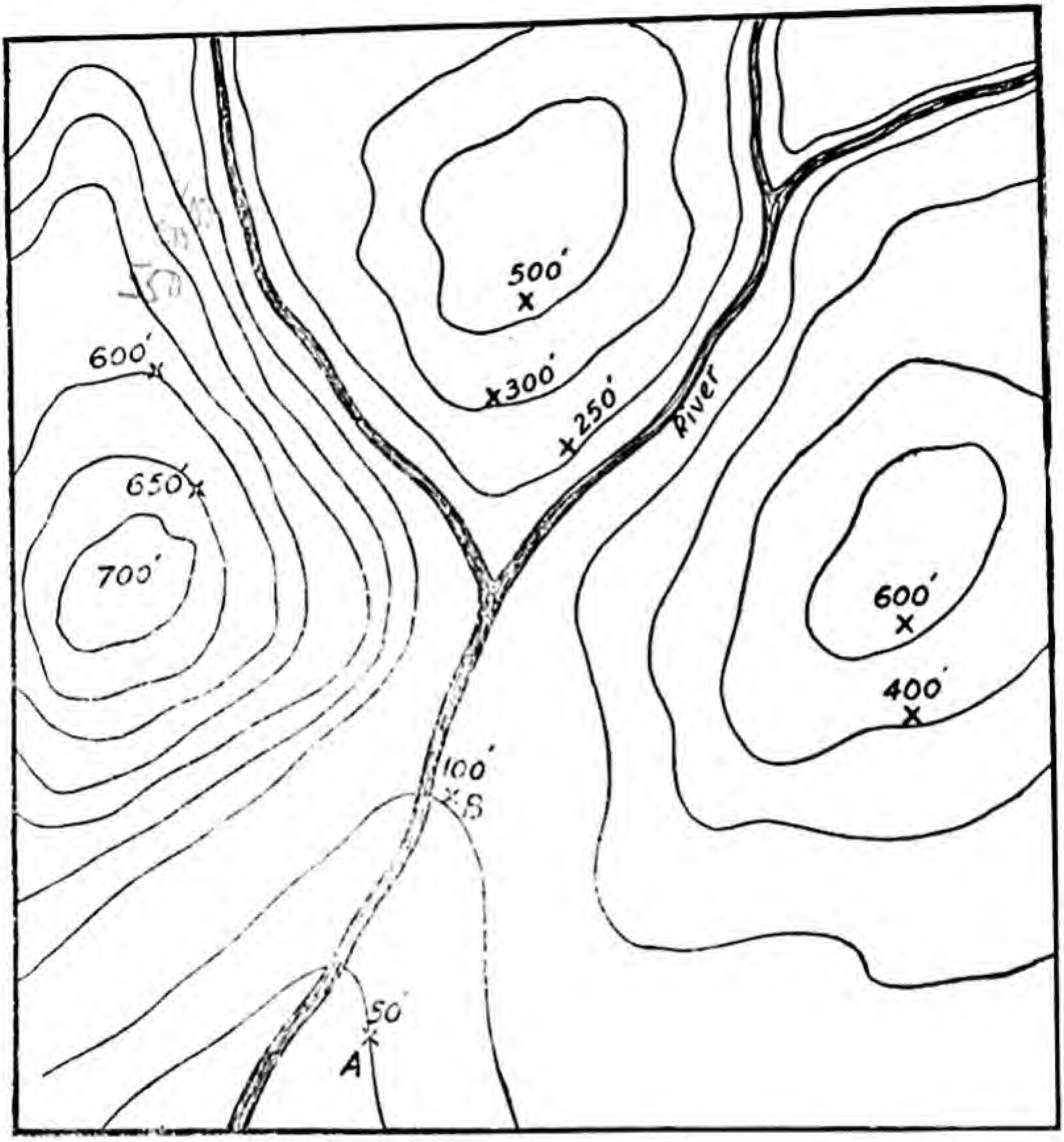


Fig. 18

While drawing the contours every fifth contour line is made thicker than the rest to facilitate reading. At the two ends, where they do not meet in the same map, or along the contour lines the height represented by them is indicated in figures.

Air Survey

Recently areas have been surveyed also by taking photographs from the air. These photographs are taken by special cameras in such a way that the areas covered by them overlap to the extent of 50 or 60 per cent. With the help of a stereoscope, these photographs supply details for maps in a laboratory.

The science of air survey is developing in India with notable success. More than 83,000 square miles have been surveyed here by air since the operations began in 1924. The air surveyor is saving both time and money needed, say, for example, in the revision of large scale agricultural and town maps, the planning of public works, the prevention of flood, or the prospecting for oil or other minerals.

Forestry and delta surveys first engaged the air surveyor's attention, because of the excessive cost of surveying such difficult terrain by normal means. The revision of large scale maps of agricultural districts and town surveys were then taken.

Before 1928, little was known about Air Survey. Pioneering work was done in this respect in Burma, the Federated Malaya States and Borneo in compiling maps of forests, rivers, coast lines and deltas. The experience gained here was put to use in producing in 1927-28 as an experimental measure a map of the Chittagong district on the scale of 16 inches to the mile.

The technique of air survey was not sufficiently developed at that time, specially for producing a map on such a large scale. Due largely to the efforts of the Survey of India, however, new methods were developed

and during the following years four complete districts of Bengal and 4,000 square miles in U. P. were mapped from the air.

Air photography is also being used for geological survey. Oil prospecting in Baluchistan was advanced by air photography when more than 1,000 square miles of land were surveyed. Important geological surveys have also been carried out in Bengal and Burma.

Distribution Maps

Distribution maps differ from topographical maps in that they show some one characteristic of the area. The question of the exact *location* of any object or feature does not arise in such maps. It is the general *appearance given by the surface distribution* of something that is emphasised by these maps. This something may be a crop; forests; some element of weather; like rain, heat or air pressure; or people. Topographical maps, on the other hand, try to locate almost every fixed object on the surface. Within the limits of the scale, i.e. the size of the map, they include every fixed detail, of whatever type. In short, the distribution maps give the *areal distribution* of a certain element.

The distribution maps are classified broadly into two classes:—

(i) Maps of qualitative areal distribution,
(ii) Maps of quantitative areal distribution.

Qualitative Maps

The maps of qualitative areal distribution are of two general types:—

(*a*) Maps of simple areal distribution. They

show the area covered by a particular element. Thus, a map showing the area covered by forests, irrespective of the different types of forests found there, is a map of simple areal distribution.

(*b*) Maps of compound areal distribution. When a distribution map shows the different types of the same element, it is a map of compound areal distribution. Thus, a forest map which shows distinctly the distribution of the coniferous type of forest, the deciduous type of forest, and the evergreen type of forest belongs to this category.

The qualitative distribution on maps may be shown either by colouring the area or by marking it with symbols or patterns. The colour method is called the *choro-chromatic* method, while the symbol method is called the *choro-schematic* method.

Quantitative Maps

A map sometimes shows the quantitative variation in the distribution of an element. There is a greater density in distribution in one section of the Map than in the other. To prepare these maps it is not enough to know where a certain thing is found, but *how much* of it is found. The basis of the quantitative maps is supplied by the statistics issued by the governments or other recognised bodies. Unlike the topographical map, the data for the quantitative distribution map are collected by the statistician and not the map-maker. The main purpose of the quantitative maps is to provide a visual help for statistical comparison of various areas. It is not the object of this type of map to be a source of statistical information about individual places or areas.

This information is best supplied by the statistical reports themselves which are the basis of these maps. Its main object is the comparison of areas. This map also shows the influence of geographical factors on the distribution of that particular element.

There are three main types of the quantitative distribution maps:—

(*a*) The isopleth maps,
(*b*) The dot maps, and
(*c*) The choropleth maps.

Isopleth Maps

Isopleths are lines connecting places of equal density or value on a map. Such lines may be isotherms, which connect places of equal temperature, isobars (equal pressure), isohyets (equal rain), or isohypses (lines of equal height, i.e., contours). The lines are drawn only for selected intervals, so that the map may not be overcrowded. For overcrowding in a map mars its value as a means of quick grasp.

The isopleths can be drawn only from accurate data, if they are to serve their purpose. They can be drawn only for areas where the distribution is fairly transitional, i.e. where a certain gradation can be fixed. On the other hand they cannot be drawn for those elements whose distribution is too varied. For this reason isopleths cannot be used for showing the distribution of crops. The distribution of crops is too variable.

Dot Maps

Where the distribution of elements is too varied

or where there is no transition in it, the variation in the distribution is shown by dots. A certain value is fixed for each dot and the data to be represented are divided by this value to get the number of dots that will be placed on the map. The value of the dot to be fixed will depend upon the quantity to be represented and the scale of the map. For example, if the total output of wheat to be represented on a map is 25,00,000 mds. and the map is small, the value of the dot will have to be fixed high, say 5,000 mds. This will give a fewer dots which can be easily accommodated on a small map. If the map is a large one, the value of the dot will be fixed low, so that there will be many dots to fill the map.

While placing the dots on the map, the geographical conditions determining the distribution of the thing should be carefully considered. The dots should, therefore, be placed only in those parts of the map where the thing is expected to be. The dots representing the distribution of wheat should thus be placed where there are plains, not on hills. Besides, every dot should be placed in the centre of gravity.

Sometimes, different shapes of the dots are used for showing the distribution of two or more different things. Thus, for example, round dots may be used for one thing and square dots for another. Dots of different sizes are also used sometimes for different units. Larger dots are then given a higher value than smaller dots. In short, the dot method can be easily adapted to different needs.

Choropleth Maps

When lines or shadings are used to cover different areas on the map to give them different values, the map is called a choropleth map. Such maps show the ratios or percentages of certain distributions. In order to make the areas distinct, different kinds of lines or shadings are used.

Exercises

1. What is a map? Describe how it is made.
2. Classify maps into important types.
3. Give a brief survey of the origin of topographical mapping.
4. What do you understand by triangulation? Illustrate your answer by imaginary sketches.
5. What is a 'traverse'? Explain the method of surveying by traverse.
6. Explain, with the help of sketches, how you would carry out graphic triangulation with a plane-table.
7. What is surveying? Classify it according to its degree of accuracy.
8. What is a Field Book? Make an imaginary Field Book and plot its data.
9. Explain, by means of sketches, how the error in traversing is adjusted in plotting.
10. Describe, with the help of sketches, how you would carry out a boundary survey of a field.
11. What is a 'triangle of error'? Explain, by means of sketches, how you would demolish it.
12. Describe the tracing paper method of resection.
13. Describe the method of 'contouring' in the field.
14. What is a 'distribution map'? Explain fully. Describe how it is made.

CHAPTER II

MAP READING

Map reading is the art of making in the mind a rational picture of the ground represented by a map. Success in this art, therefore, requires a considerable practice. A map usually shows all sorts of details in a conventionalised manner. It is only the practised mind which can pick out quickly and correctly the required information from it.

The simplest form of map reading is *descriptive* which merely identifies and describes the various features depicted on a map. Descriptive map reading is all that is needed in military strategy or route marching. But for the geographer map reading should also be *analytic* and *deductive*. He should not only describe the facts shown on the map, but also analyse them and make deductions from them. This wider form of map reading demands not only the knowledge of conventional symbols, but also the understanding of Physical Geography.

The first step in map reading is to familiarise oneself with the symbols used in the map. These are usually given at the bottom of the map. The portion of the map which gives these symbols or signs is called '*the characteristic sheet*.' A fuller characteristic sheet giving all signs used by the map makers in a particular

country is, however, printed separately by the government of that country. In India, it is printed by the 'Survey of India' at Calcutta.

The number, size and character of the symbols used will depend and vary with the scale and the object of the map. If the scale is large and a great variety of details is to be shown, the corresponding symbols or signs will also be varied accordingly.

The other steps necessary in map reading are to note:—

(i) the scale and grasp of the actual length of the ground shown by it;
(ii) the shape and the V. I. of the contours;
(iii) the drainage system which helps in visualising the general nature of the ground;
(iv) prominent features which help in identifying other objects, and determining your position on the map.

In map reading it is necessary that one should think in terms of relief. It is thus that one gains the ability to visualise the actual country which is so essential for a successful map reading.

MAP-SETTING

To read the map in the field is to identify the objects there with their representations in the map. This cannot be done successfully without 'Setting' or 'Orienting' the map. Setting or orienting the map means placing it in such a way that the objects shown on the map will appear in the same *direction* as their actual counter-parts on the ground. In other words, the

NORTH point of the map points to the north point of the field.

A map may be set by:—

(i) Compass; or

(ii) Objects recognisable both on the map and in the field; or

(iii) the Sun.

(i) By Compass

(*a*) Bringing the needle to coincide with the line of the magnetic north.

On most of the survey maps in use a line pointing to the magnetic pole of the earth is drawn in one corner. This line is often shown forming an angle with the line showing true north which points to the geographical North Pole. To set the map with the magnetic line, place the compass on the map in such a way that its axis (0°—180°) lies exactly on this line. If necessary, produce the magnetic line. Then release the compass needle which will then move. Now, turn the map round slowly without disturbing the compass until the needle coincides with the line of the magnetic north. As soon as this happens the map is set.

The direction of the magnetic north changes frequently and it is not, therefore, certain that the line of the magnetic north shown on an old map will coincide with the magnetic needle. This variation in the direction of the magnetic north can be shown by quoting the example of Paris, where the longest records of magnetic observation exist. In 1580 the magnetic line formed with the true north-south line an angle of 9½° to the east of it. In 1810, however, this angle measured

$22\frac{1}{2}^\circ$, to the west of the line. At London, this angle measured 12°, $13{\cdot}7'$ W. in 1931 and 11°, $9{\cdot}5'$ in 1937. The magnetic variation for India is, however, negligible at present. For Allahabad it was 0°, $10'$ W. in 1931.

In cases of considerable magnetic variation, therefore, it becomes necessary to find out the actual variation for the year and on that basis make an angle with the north-south line on the map. The new line drawn to form this angle should now be used for setting the map.

(*b*) Taking the bearing of a distant object which can be recognised on the map.

Take by means of the compass the bearing of a prominent and distant object in the field. On the map now draw a line connecting your position with this object. Place the compass on this line so that its axis (0°—180° line) coincides with it. Now, turn the map round until the degree of the bearing on the inner circle of the dial is opposite to the lubber mark inside the box. The lubber mark is a fixed mark on the compass in direct line with the sight-line. This method of map-setting eliminates the question of magnetic variation or compass error. It can be followed without the help of the north-south line.

(ii) By Recognisable Objects

(*a*) From known position (Fig. 19 A).

When you can recognise on the map your own position and also that of some prominent object in the field, join the two points on the map by means of a pencil. Now rotate the map until this line actually

points to the distant object in the field. The map is now set. This is the easiest method and eliminates all questions of magnetic variation.

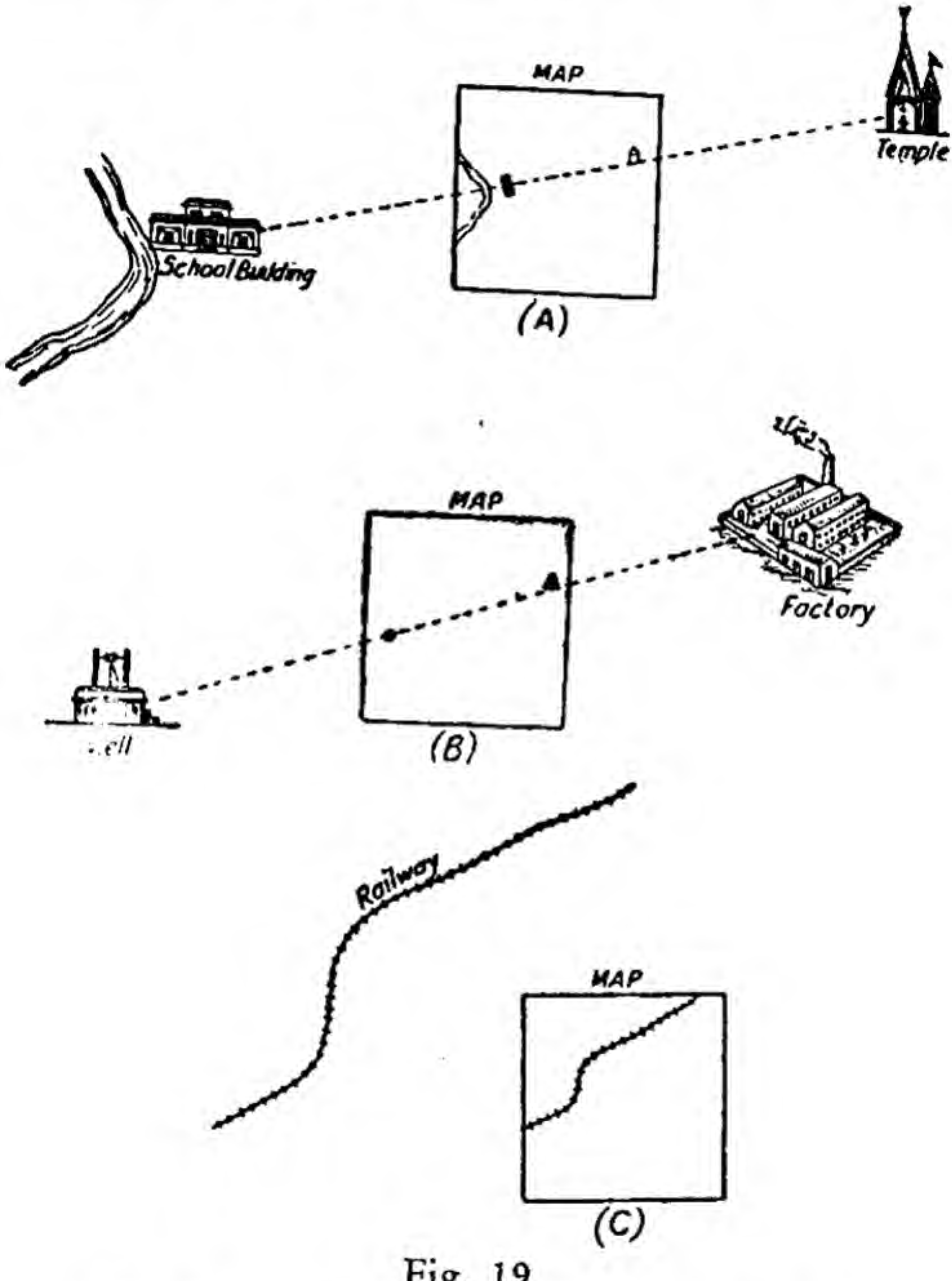


Fig. 19

(*b*) From unknown position (Fig. 19 B).

When your exact position on the map is unknown, but when you can recognise on the map two prominent

objects in opposite direction in the field. Now, place yourself between these objects. Join the two points representing these objects on the map. Turn the map until the line on it points to the objects in the field. The map is thus set.

(*c*) From straight features on the map (Fig. 19 C).

When you can recognise on the map some road, canal or railway line, select its straight stretch. Then hold the map in such a way that its representation on the map is parallel to the actual stretch in the field. This method is only approximate.

(iii) By the Sun

(*a*) With a Protractor.

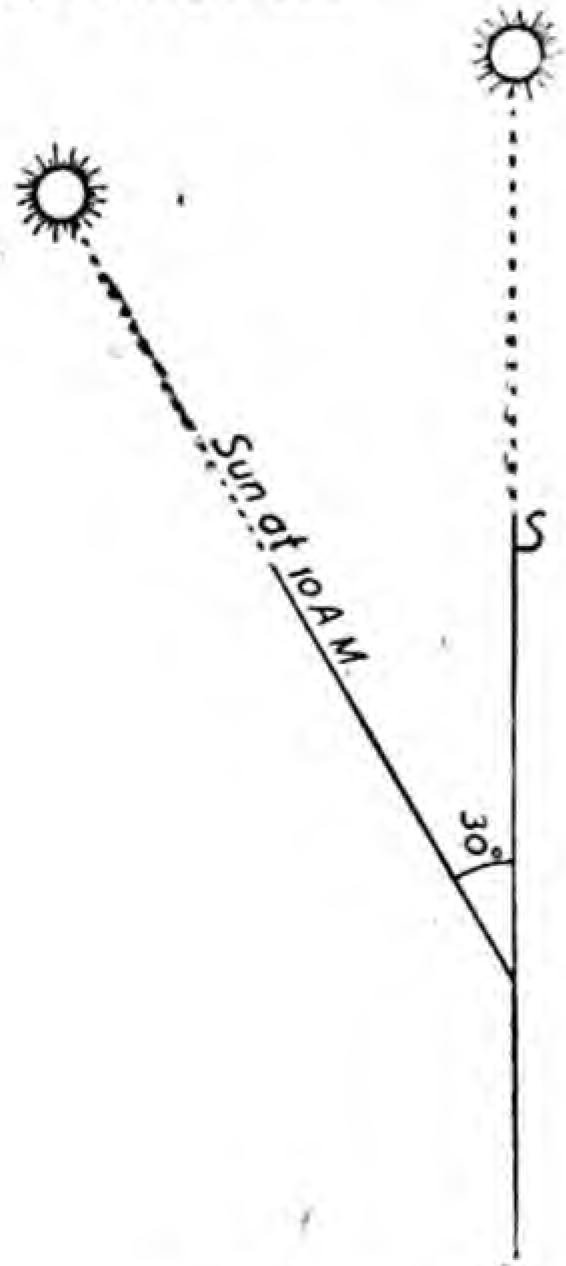


Fig. 20

In the Northern Hemisphere the sun is due south, for places north of the Tropic of Cancer, at noon. It travels 15° for every hour in a clockwise direction. By noting the time of the day we can know the number of degrees it has travelled beyond or is short of the north-south line. Suppose it is 10 a.m. i.e. there are still two hours before noon. In two hours the sun will travel 30°. We, therefore, make an angle of 30° with the north-south line of the map to the east of it. Now, place the map in such a way that the line making this angle with the north-south line faces the sun. The map will then be set. (Fig. 20)

Sometimes, a large pin is stuck at the end of this line which will throw a shadow. Now, turn the map until this shadow falls along the line.

(*b*) With a Watch.

Hold the watch face upwards and turn it so that the hour hand points towards the sun (neglecting the

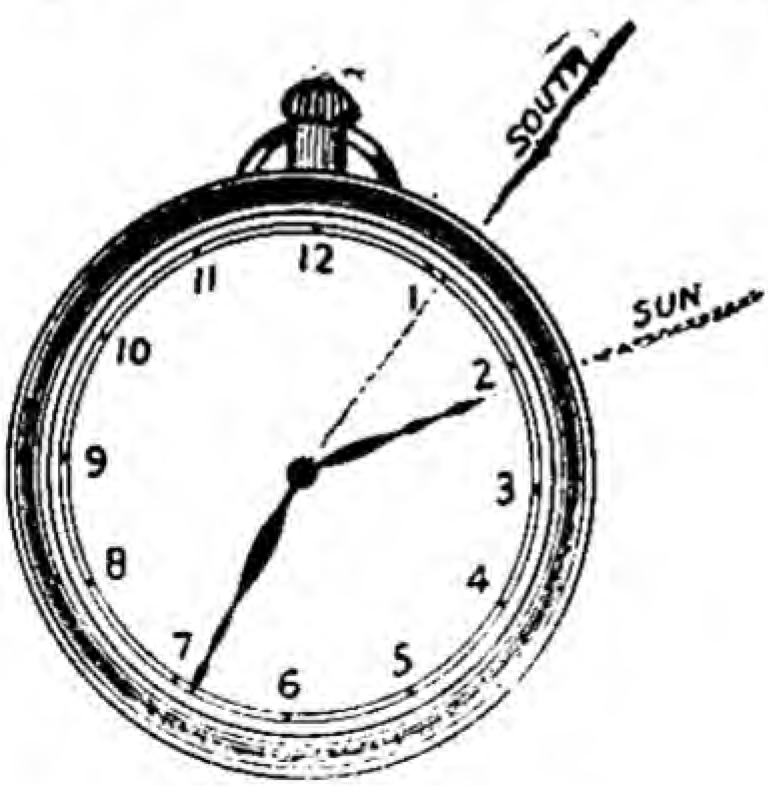


Fig. 21

minute hand). Now imagine a line dividing the angle formed by the hour hand and an imaginary line from

the centre of the dial to the figure 12 on it. This bisecting line will show the south in the northern hemisphere. Now, holding the watch steady turn the map slowly until the north-south line on the map coincides with the bisecting line. The map is set.

[NOTE—When summer time, which is one hour ahead, is used, the figure of 1 instead of 12 should be used.]

Fig. 22

The north is also determined at night by the Pole Star (Polaris). To set the map its north point should be turned towards the Pole Star. The Pole Star can be easily found in the heavens with the help of the 'pointers' in the Great Bear. The above diagram shows this.

SCALE

Distances between objects on the ground can be measured from the map, because every map bears a fixed ratio to the ground it represents. This ratio is called the *scale* of the map. The scale, therefore, expresses the relationship which the distance between two points on the map bears to the horizontal distance separating them on the ground. To find out distances from the map this *ratio between the map and the ground* must be known.

The scale is, therefore, clearly expressed on every map. There are three ways of expressing it:—

(i) By a simple statement; e.g. Scale 1 inch to 4 miles. This means that four miles on the ground are represented by one inch on the map.

(ii) By the ratio, known as the Representative Fraction (R. F.); e.g. 1 : 253440. This means that one unit on the map represents 253440 units on the ground. The advantage of expressing the scale by R. F. is that it can be converted into any unit of measurement. For this reason it is applicable to maps produced in any country irrespective of the unit of measurement used. For instance the above R. F. can mean '1 cm. on the map represents 253440 cm. on the ground'; and also '1 inch on the map represents 253440 inches on the ground'.

(iii) By Plain Scale. This is a graphical representation of the scale for quick reading.

It has the advantage that the distances can be found out without the need of any conversion or calculation. All that is necessary is to tick off the desired distance on the map on a paper and place it on the scale. The actual distance on the ground can now be read off the scale.

The plain scale is a straight line drawn on the map and subdivided on the same ratio as the map bears to the ground. The subdivisions are marked by the distances that they will show on the ground. The major divisions to the right are called the 'primary' divisions; while the minor divisions to the left are called the 'secondary' divisions. The primary divisions are for whole numbers, and the secondary divisions are for decimals.

Sometimes, the secondary divisions are divided in a special way which gives the DIAGONAL SCALE. This scale enables two decimal places to be read off it.

The plain scale can be adapted to show various types of measurements. Thus, there may be a 'scale of paces', a 'scale of revolutions', or a 'time scale'. The object of these scales is to determine, without actually measuring the ground, the distance that has been covered after a number of paces, revolutions, or time.

Construction of the Plain Scale

To construct the plain scale, draw a straight line of suitable length (say, 4 to 6 inches), and subdivide it into a number of equal parts. Each subdivision should be on the scale on which the whole map is drawn. Starting from the left, reserve the first subdivision for

decimal or minor subdivisions, called the secondary divisions. Number the rest from 0 (zero) onwards towards the right. These are the primary divisions. Now, subdivide the division to the left of the zero into ten equal parts, if the decimals are required, or into any other desired minor subdivisions and number them from the zero to the left.

On a map drawn on a scale of 1 inch to a mile draw a straight line, say, 5 inches long. Subdivide it into five equal parts and number as in Fig 23.

To divide a straight line accurately, draw another straight line of sufficient length making with it an angle of 20° to 30°. Divide this line into the number of sections required. Draw parallels from the points of division to the first line, the scale line. The points where these parallels intersect the line are the required points of subdivision. Rub off the parallels and the second line. This process is shown in Fig. 24.

When the primary divisions have been made, the secondary divisions should be made, in this case, into quarter miles, as the scale shows miles. The scale will then appear as in Fig. 25.

If the scale of the map were 1½ inches to a mile, a line of six inches, divided into four parts of 1½″ each, would be drawn. The first part would be left for secondaries and the rest would give three primaries.

This is a simple case of plain scale construction where the unit of measurement of the scale is indicated.

In other cases, the unit of measurement is not given, and it has to be found out first and the suitable length of line to be determined before the plain scale can be constructed. Such a case arises when the scale

Fig. 23

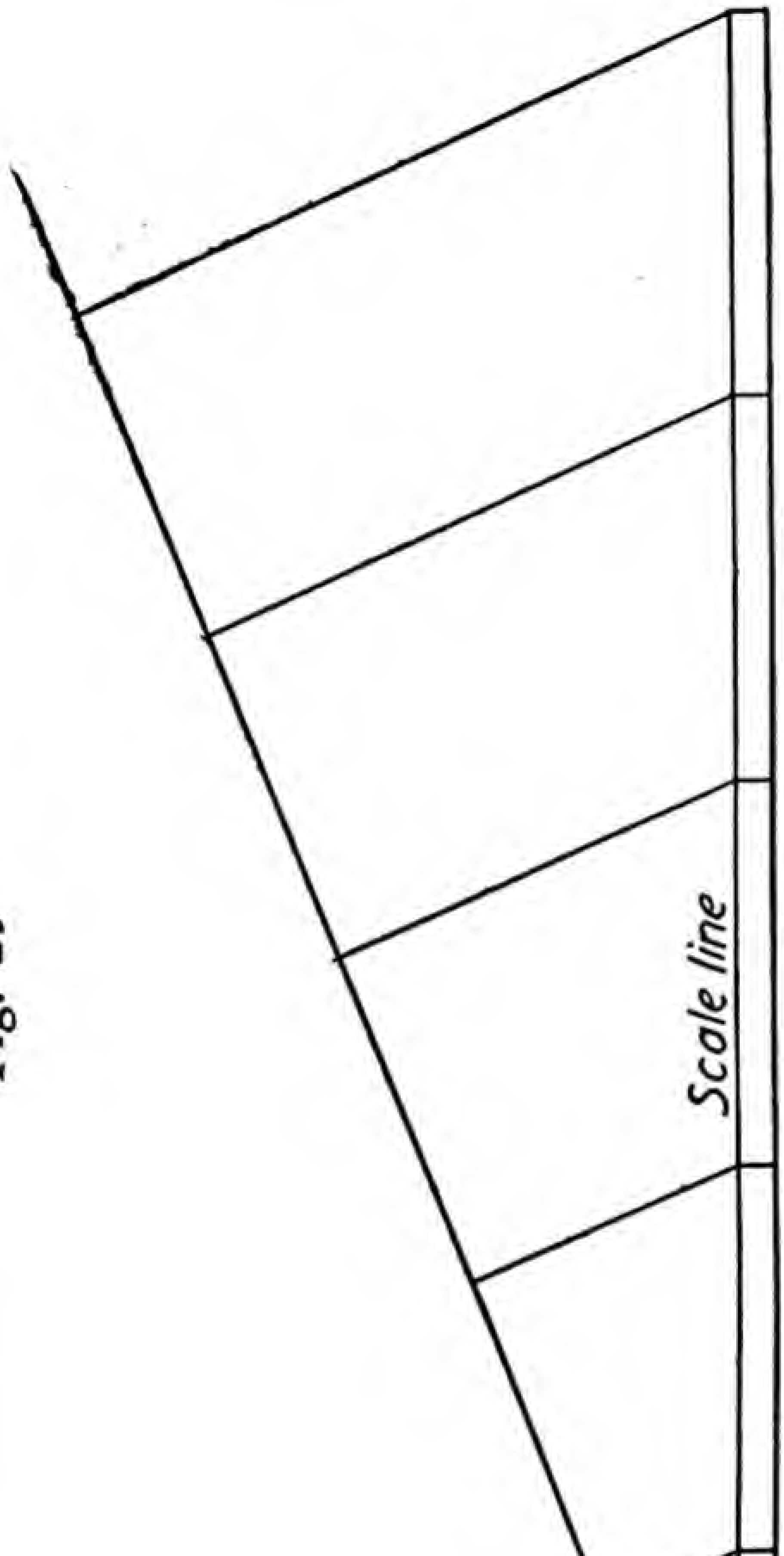


Fig. 24

Fig. 25

has to be constructed from an R. F.

The first thing to be done in this case is to find out the unit of measurement. If the map is drawn on a *small scale*, several miles on the ground would be represented by one inch on the map. If, on the other hand, the map is drawn on a *large scale*, one mile on the ground would be represented by several inches on the map. The measurement of the scale in each of the above cases is found out by following the rules given below:—

When the R. F. is given:—

1. **To find miles to an inch, divide the denominator of the R. F. by 63,360.**
2. **To find inches to the mile, divide 63,360 by the denominator of the R. F.**

Having found out the measurement, draw a straight line of sufficient length to represent a round number of miles. Then divide the line into primaries and secondaries according to the method given above.

To draw the plain scale of the R. F. 1/100,000, divide 63,360 by the denominator 100,000. This gives us ·634 inch. This is the measurement by which 1 mile is represented on the map with this scale. Now, draw a line of a length to represent 5 miles. This length is about 3·1 inches (·634 multiplied by 5). Divide this line into five equal parts; four primaries and one secondary. The secondary may be divided into quarter miles. The scale will appear as in Fig. 26.

In large scale maps where one mile on the ground is represented by several inches on the map, the practice is to draw the plain scale showing yards.

To construct a plain scale for 1/25,000 showing yards, divide 63,360 by the denominator 25,000. This will give us 2·53 inches to represent 1 mile or 1760 yards. As 1760 is not a convenient number for subdivisions, we shall take 3000 yds. for representation. If 1760 yds. are represented by 2·53 inches, 3000 yds. will require 4·3 inches. This is found out by arithmetic. Now, draw a straight line of 4.3 inches and divide it into two primaries for 1000 yds. each, and one secondary subdivided into four sections for 250 yds. The scale will then appear as in Fig. 27.

A simpler method for constructing yard scale from an R. F. is to suppose the unit (the numerator) to be a yard which is equal to 36 inches. In the above case, 25,000 yds. on ground are thus represented by 36 inches on the map. Therefore, 2,500 yds. will be represented by 3·6 inches. Now, divide a line of 3·6 inches into four primaries of 500 yds. each and one secondary into five sections of 100 yds. each.

A **Scale of Paces** is sometimes appended to the scale of yards to determine the distance covered by a certain number of paces. The standard military pace is 2½ feet or 120 paces to 100 yards. Under the 100 yds. section of the scale, therefore, should be written '120 paces'.

A **Time Scale** is also added to maps used in marching. For this purpose, the speed of march per hour is given and the scale of the map is also known.

To construct a time scale for the speed of 2½ miles per hour on a map drawn on the scale of 4 miles to one inch, select a suitable number of hours. Find out the distance that will be covered within this time.

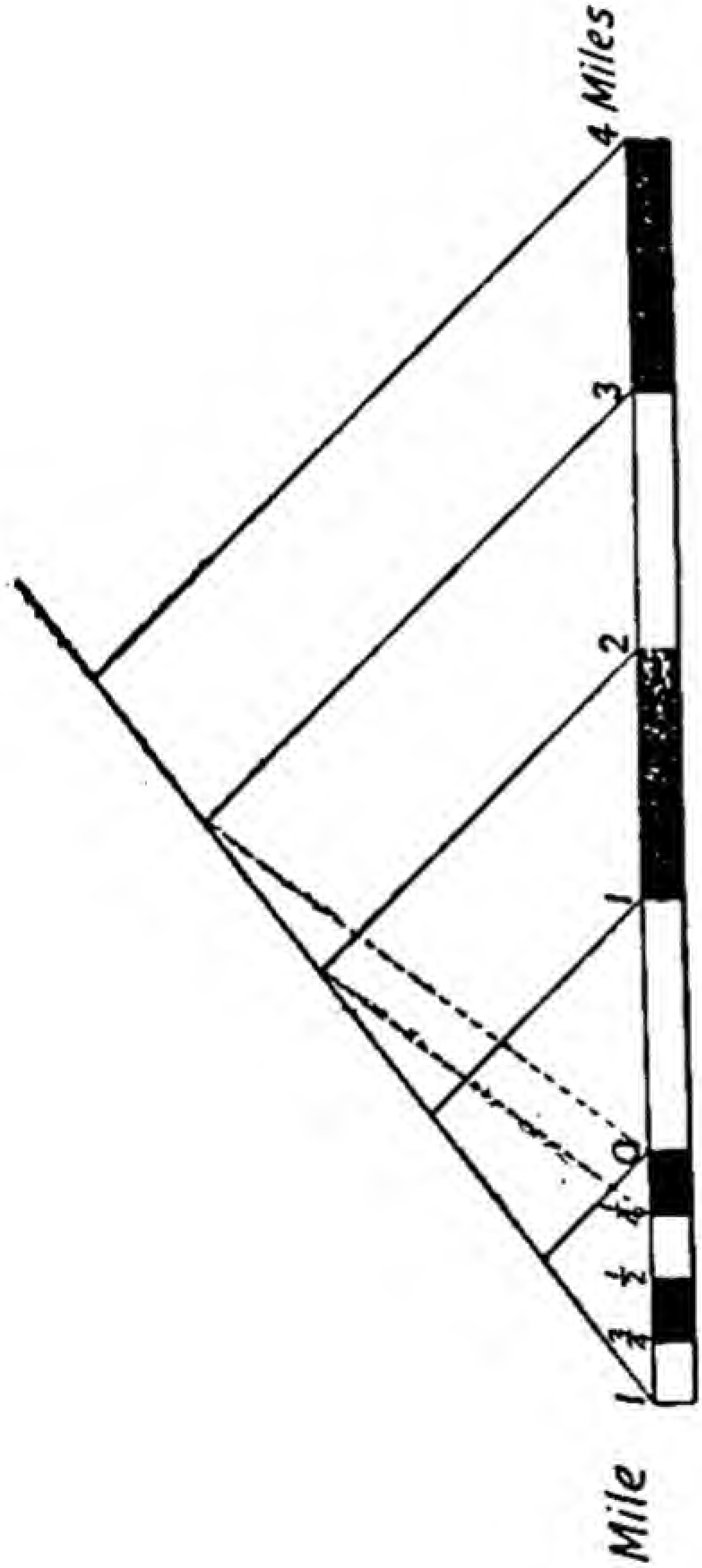


Fig. 26

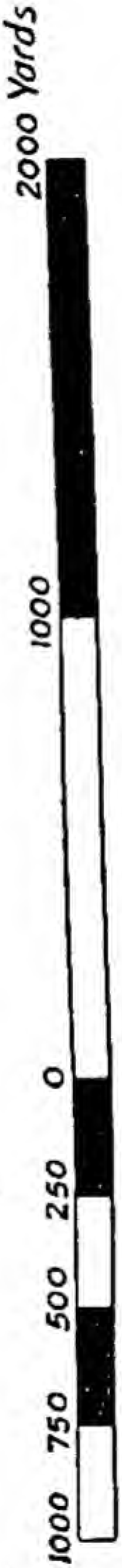


Fig. 27

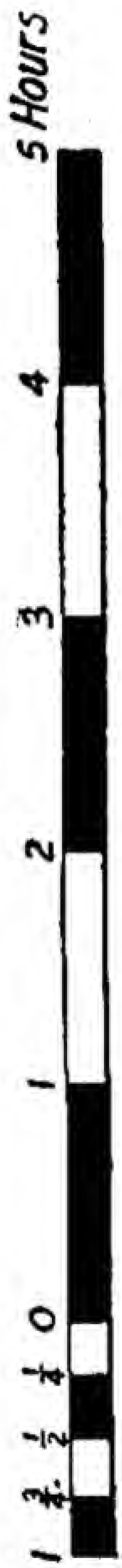


Fig. 28

Then draw a straight line to represent this distance on the scale of the map. Divide this line into the number of *hours* and mark the usual primaries and secondaries. Suppose the number of hours selected is 6. Then the distance covered at 2½ miles per hour will be 15 miles. At 4 miles to an inch this distance will be represented by 3¾ inches. Now, draw a straight line of this length and divide it into six equal parts representing hours. The secondary may be subdivided into quarter hours. The scale will appear as in Fig. 28.

We have so far explained the method how the plain scales are constructed. In practice, however, it is seldom necessary to construct the plain scales in map reading. The necessary scales are given on a protractor, and they can be copied on the map, if desired.

A DIAGONAL SCALE is a device for dividing the secondary of a plain scale very accurately. Usually, however, this method is used for providing a decimal scale. To construct a diagonal scale for reading decimals, draw ten equidistant parallel lines above the scale line. Divide the top and the bottom lines of the secondary portion only into ten equal parts. Number these parts from 0 to 9 to the left. Now, join the 0 on the top to the 0 at the bottom, and the tenth part on the top to the tenth part at the bottom. This gives us a rectangle over the secondary. Then, join 1 on the top to the 0 at the bottom, 2 on the top to 1 at the bottom, 3 at the top to 2 at the bottom, and so on until all the points of division are joined. This completes the diagonal scale. On this scale, the sections on the original scale line at the bottom show distances to one decimal place, while those on the successive parallels show dis-

tances to two decimal places. To read ·57 on this scale, reach the point marked 5 on the scale line at the bottom and from there follow the diagonal line upward until you reach the parallel line marked 7. The intersection of the diagonal line (marked 5 here) and the parallel line (marked 7 here) gives the required distance. The following shows the construction of the diagonal scale:—

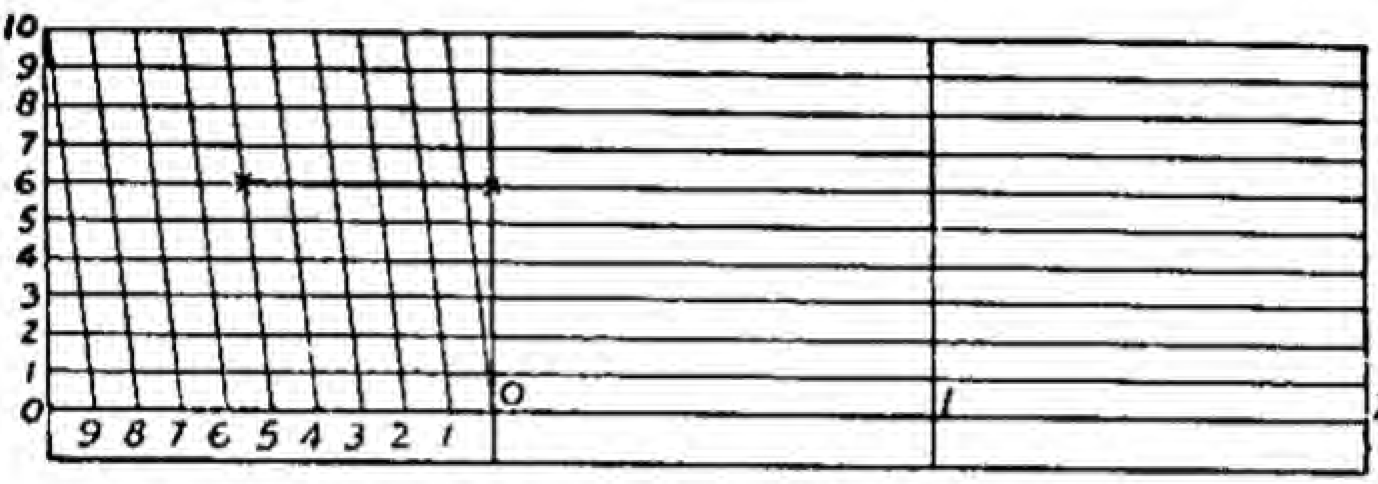


Fig. 29

Conversion of the Scale into R. F.

Sometimes, it becomes necessary to express the scale, shown by a simple statement or graphically, by R. F. In such cases the simple rules are:—

1. When the scale is given in miles to an inch; i.e. in small scale maps, *multiply 63,360 by the miles given. This gives the denominator of the R. F.*
2. When the scale is given in inches to a mile; i.e. in large scale maps, *divide 63,360 by the inches given. This gives the denominator of the R. F.*

For example, if the scale is 4 miles=1 inch,
the R. F. will be

$$63{,}360 \times 4 = 253{,}440$$
$$= 1/253{,}440.$$

Or

If the scale is 6 inches=1 mile,
the R. F. will be

$$63{,}360 \div 6 = 10{,}560$$
$$= 1/10{,}560.$$

Measuring distances from the Plain Scale

The measurement is generally done with the help of a pair of dividers. The distance between two points on the map is first got by opening the points of the dividers. Then place one point of the dividers at 0 on the plain scale, and the other point on the line as far as it will go to the right. Suppose it is found that the distance is more than 4 miles. Then place one point of the dividers at the mark representing 4 miles, and let the other point touch the secondary division. Note where the point touches the secondary, add it to the 4 miles read on the primary division. Suppose here it touches the section marked ½. Then the distance required is 4+½=4½ miles.

If a map has no scale given, its scale can be ascertained by the fact that 1 degree of latitude is roughly equal to 69 miles. For accuracy measurement should be taken in the centre of the map. Suppose we find the measurement of 1 degree on the map to be 2 inches. Then the scale will be:—

34·5 miles to 1 inch

Or

1/2,185,920.

SCALE OF SLOPES

A scale of slopes is sometimes constructed to measure from the contours the slope of the ground between any two points. It furnishes a very rapid and convenient method of getting the slope. The scale is made by marking off along a straight line the lengths of the H. E. for every degree of slope. The lengths of the H. E. are drawn on the scale of the map. The divisions of the line representing the degrees bear a simple relationship among themselves. For example, the length representing 1° of slope is twice that representing 2° and three times that representing 3°, and so on. Therefore, all that is necessary to do is to find the H. E. of 1° and the rest can be easily computed by dividing this length by the degrees.

The formula for getting the length of the H. E. of 1° for any map is as follows:—

$$\text{H.E.} = 57{\cdot}3 \times \text{V. I. (in feet)} \times 12 \text{ (inches)} \times \text{R. F.}$$

Thus the H. E. for 1° on a map on the scale of 1/63,360 with the V. I. of 50 feet will be:—

$$\frac{57{\cdot}3 \times 50 \times 12 \times 1}{63{,}360} = \frac{34{,}380}{63{,}360}$$

$$= {\cdot}54 \text{ inch.}$$

The scale will now appear as under:—

Fig. 30

The first division will be of ·54 inch the second, of half of ·54″; the third, of one-third of ·54″; and so on.

A scale of slopes can serve only for the map and the V. I. for which it has been constructed.

For measuring the slope, take the distance between two consecutive contours on the map on a pair of dividers. Place this distance along the various divisions. Whatever division it fits or is near about, that gives the slope between those contour lines only.

CHANGING THE SCALE

Sometimes it is necessary to change the scale of the map by enlarging or reducing it. This may be done either, by a mechanical device known as the 'pantograph', or by the method of squares.

The method of squares consists in

(i) drawing squares to represent one mile *on the map* on the old scale;

(ii) drawing squares to represent one mile on the sheet of paper on the new scale;

(iii) sub-dividing the squares both on the map and on the paper into a fixed number of sub-divisions, say five sub-divisions for every mile square;

(iv) copying the detail from the map to the sheet of the paper by means of the eye, square by square.

RELIEF

Visualising of relief is an essential part of map reading. One should be able to form a correct picture of the relief of an area from its map. There are various methods by which relief is shown on a map. Among these may be mentioned the *contours*, *spot heights*, *hachures*, *hill shading*, and *layering* (or colouring). In order to get the best results, however, a combination of some or all of these methods is employed.

CONTOURS

A contour is a line drawn on the map through all the places situated at the same height above the mean sea level (M. S. L.). It is, therefore, the *line of equal height*. A contour line marked 300 on the map means that all the places that are connected by it are situated at an elevation of 300 feet above sea level. By showing elevations or slopes, therefore, the contour lines give a picture of the relief of an area. The difference in the height of two successive contours is called the Vertical Interval (V. I.).

As the elevations or slopes in nature are not distributed regularly, the contour lines which show them on the map must also be irregular. They appear on the map, therefore, as curving lines; in some places close together and in others far apart. Sometimes, they form on the map closed figures of irregular shape; while in other cases their ends pass to the edges of the map. In theory, however, the ends of the contour lines must close, for the shape of the earth is round. The round shape of the earth, thus, leads us to the principle

of the contour lines.. We know that the earth is surrounded by water which has filled the depressions, leaving the elevated portions high and dry. If the water surrounding the earth were to rise, say 10 feet, above the existing level, it will drown all places situated at an elevation of 10 feet above its old level. If this water subsides to the old level, it will leave a line mark indicating all the places that were drowned formerly. This line will be an irregular but closed line owing to the shape of the earth. The representation of this line on the map will be called the contour line.

Next time, when the water rose, say 20 feet, it will form a second line which will be higher than the first line. This rise and fall of water around the earth can be imagined to give to the map the lines indicating the elevation of various parts of the earth's surface.

This principle can be illustrated by placing a model of irregular shape in a tub and adding water to cover it. Suppose such a model to be placed in the tub in the following diagram:—

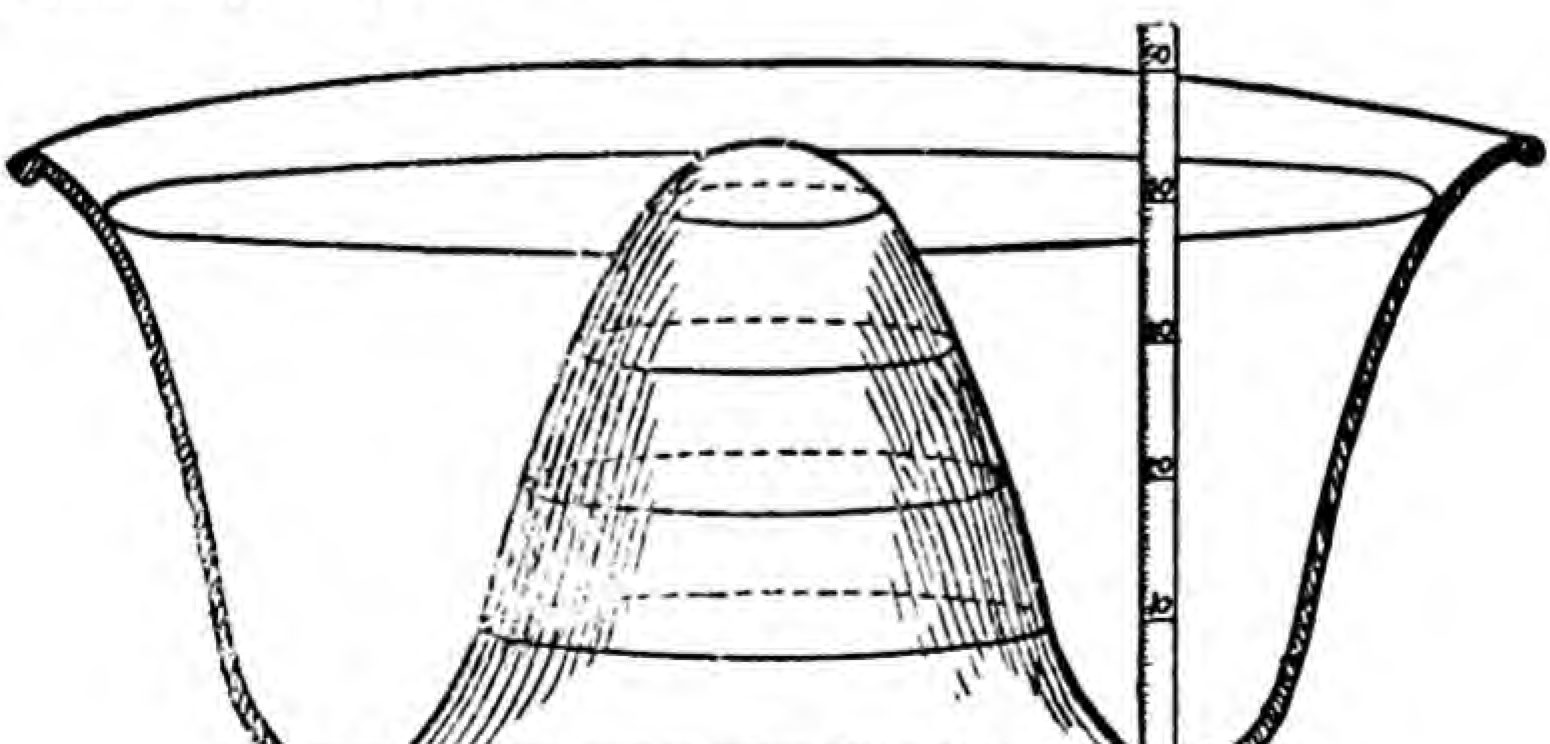


Fig. 31A

The bottom of the tub represents the shore line. When water is added to the tub it touches the first line. Successive supplies of water touch the higher lines. These lines will appear on the map as closed circles shown in Fig. 31 B.

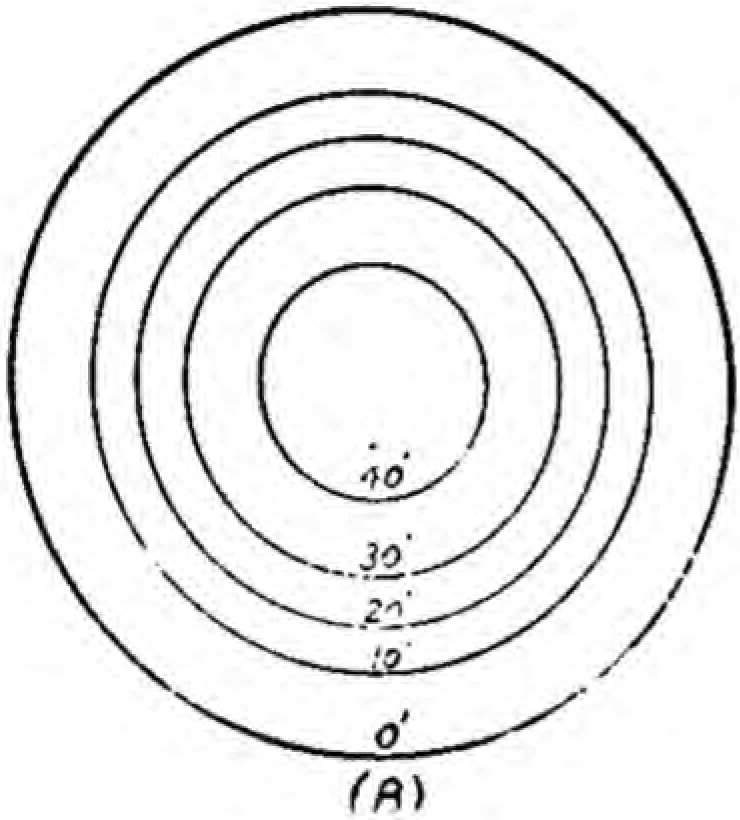


Fig. 31B

It will be remembered that when water rises it covers a large surface where the land is flattish; that is to say, where the slope is gentle. But where the slope is steep the water is heaped up without covering large area. The result is that the lines marking the rise of the water are close together, one over the other; in areas of steep slope and far apart in flat areas. This explains why the contour lines on the map are closer together in areas of steeper slopes than in those of gentler slopes.

Sometimes, it is not possible to survey the accurate contour lines. In such cases *Form Lines* are used. They are approximate contours and are shown on the map as broken lines in contrast with the continuous lines used

for contour lines. They are not necessarily drawn at regular intervals and are not reliable for accurate information.

In Fig. 32 is shown how certain forms of relief appear on the contour map.

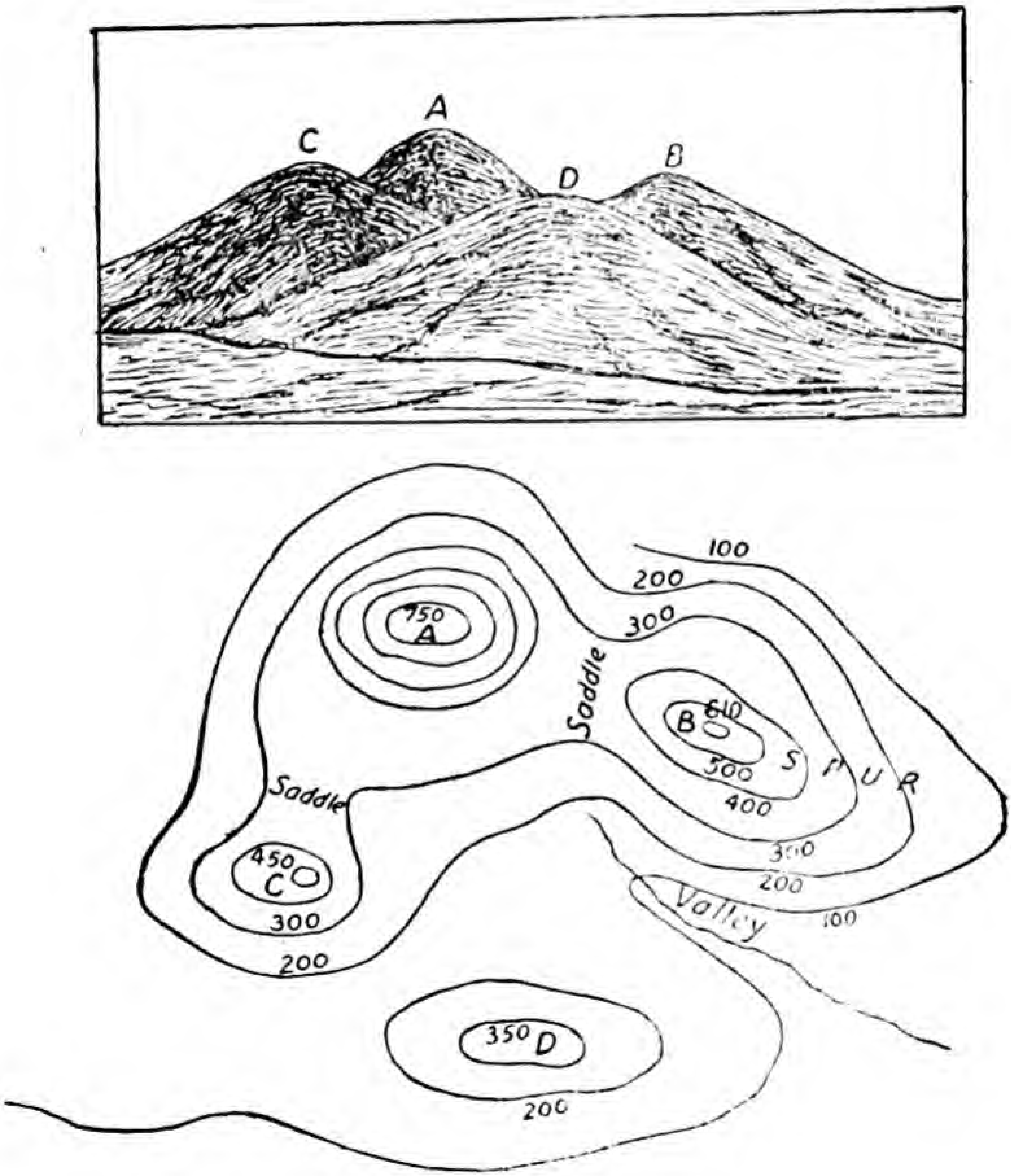
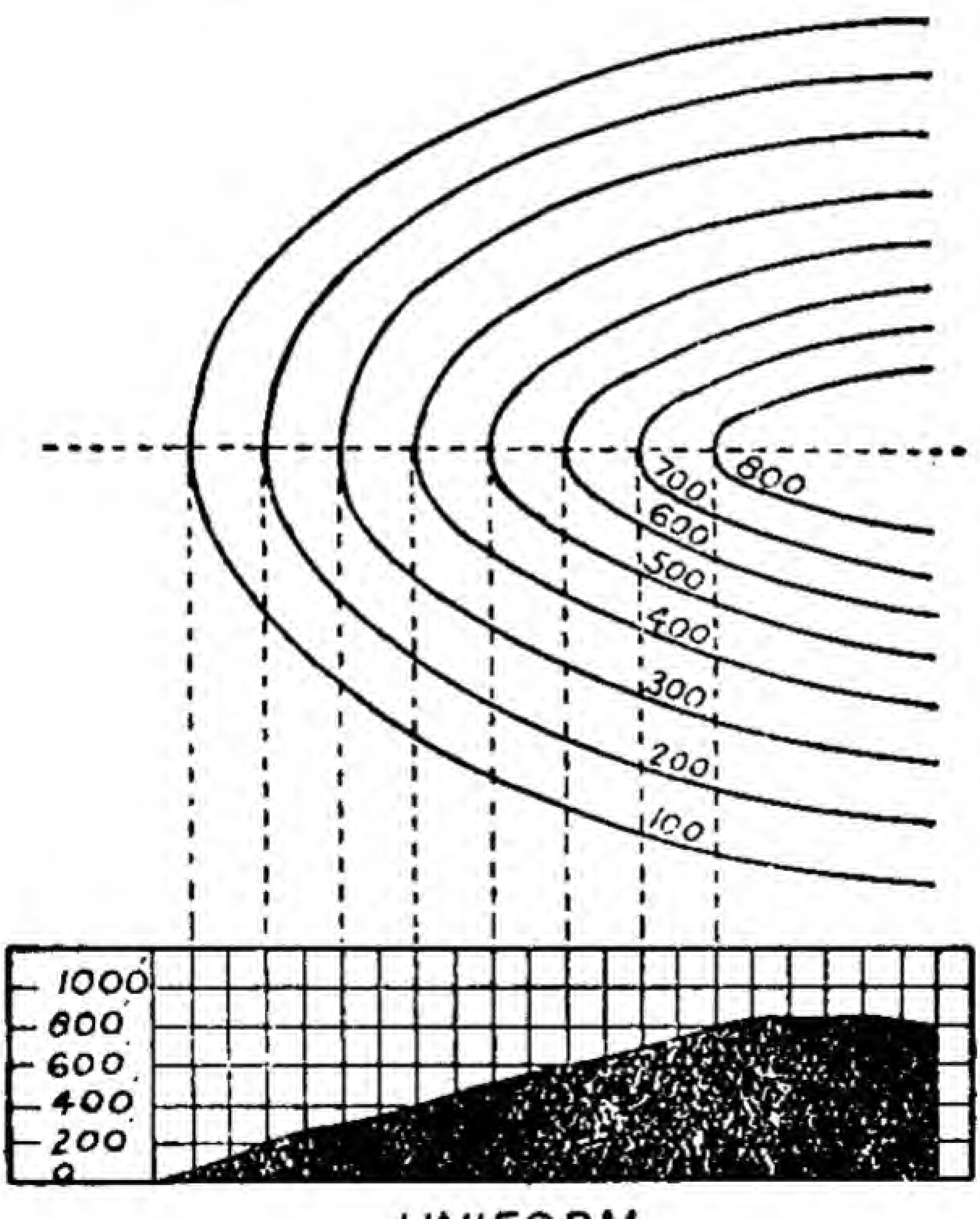


Fig. 32

In the diagram, four characteristic shapes of contour lines will be noticed:—

(1) Closed contours, showing hills;
(2) Contours bending away from the hills, showing spurs and salients;
(3) Contours bending towards the hills, showin valleys or re-entrants;
(4) Contours joining hills, showing saddles.

By a little practice these characteristic shapes will help us to form a mental picture of the various relief features they represent.



UNIFORM
Fig. 33

Contour lines give us an idea of the slope of the ground also. Where they are drawn close together the distance to be travelled forward is small in comparison with the height that has to be climbed. This indicates a steep slope of the ground. Where, on the other hand, the contour lines are drawn far apart, the distance to be travelled forward to the next contour line is long compared with the height to be climbed. This indicates a gentle slope.

A survey of the land surface reveals that the slope of the ground is of three classes:—

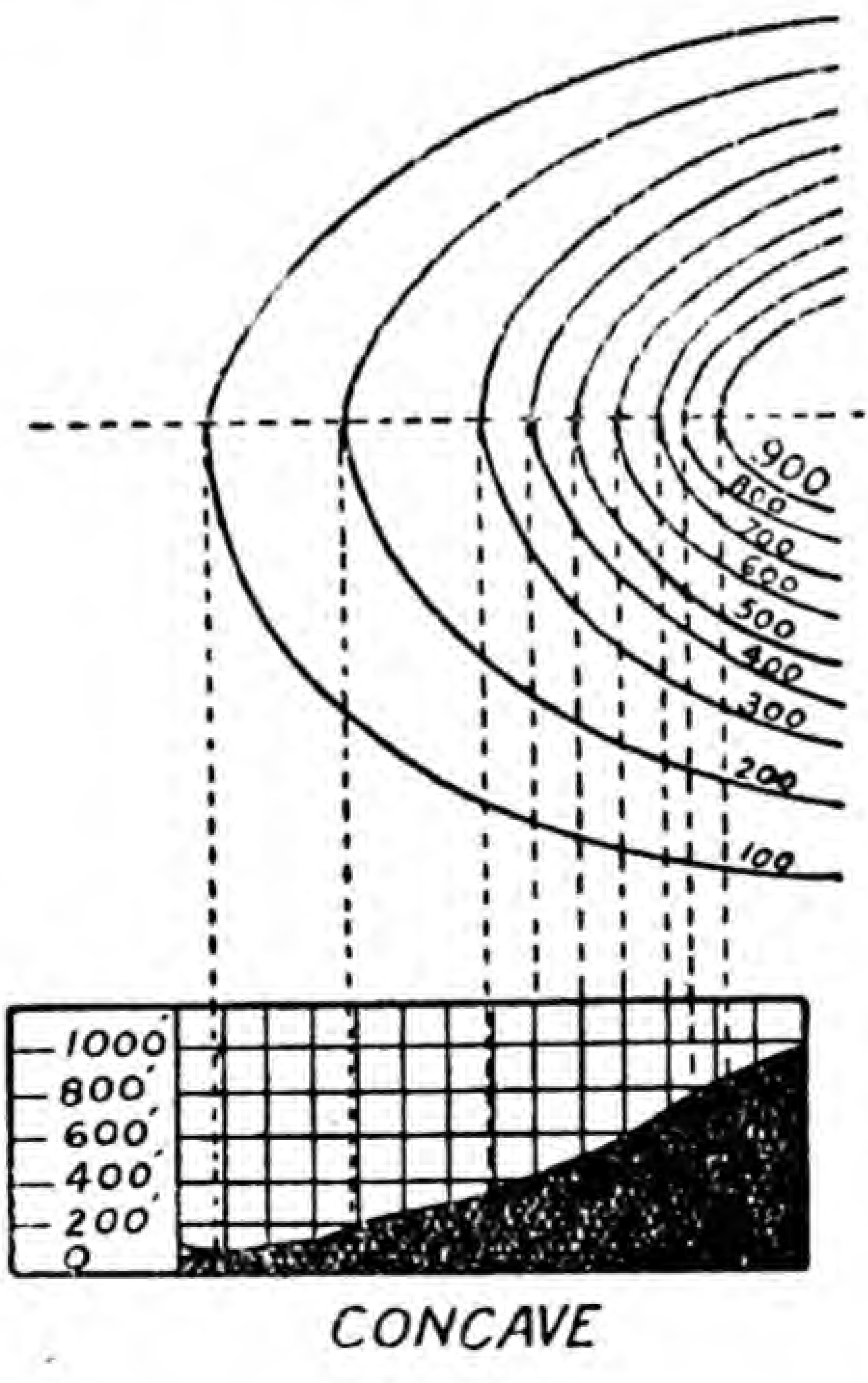


Fig. 34

1. Uniform slope, where the ground has the same type of slope throughout. This type of slope is represented on the map by the contour lines being equidistant (fig. 33).
2. Concave slope, which begins with a steep slope at the top but ends with a gentler slope at the bottom. This is shown on the contour map by the higher contours being close together and the lower contours being wider apart (fig. 34).

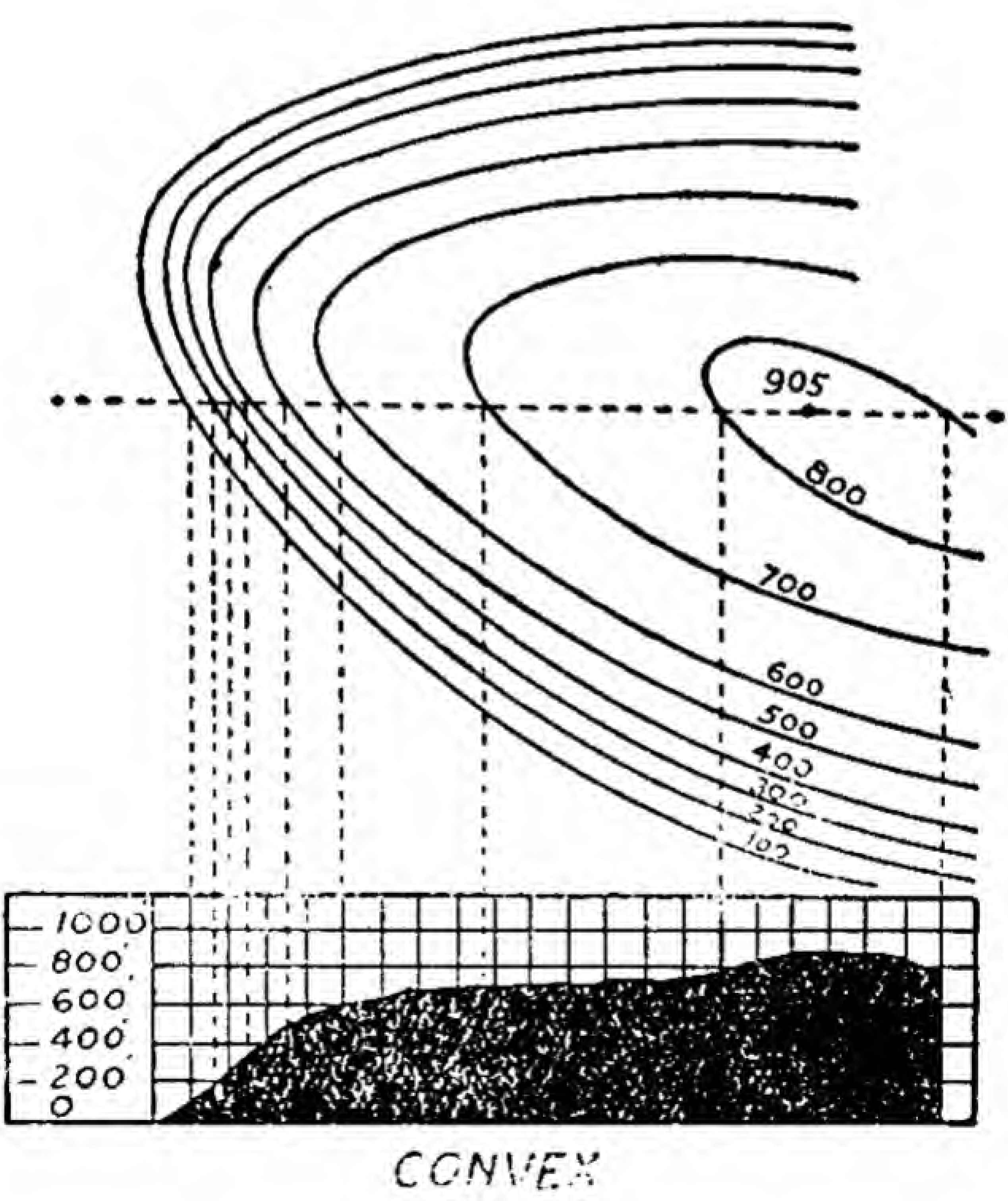


Fig. 35

3. Convex slope, which begins at the top with a gentle slope, but ends at the bottom with a steeper slope. It is shown on the map by the higher contours being wide apart and the lower contours closer together (fig. 35).

Generally, the contours representing a *valley* are further apart at the bottom than at the top and, therefore, its sides are *concave*. The contours representing a *spur*, on the other hand, are closer together at the bottom than at the top and, therefore, its sides are *convex*. The figures showing the height of the contours are always placed on the side of the line on which the ground rises. The direction of the slope can, therefore, be known even by looking at the placing of the contour figures. Similarly, the top of a hill or the bottom of a valley may be recognised on the map by the presence of two adjacent contours marked with the same height.

In map reading, it becomes necessary sometimes to measure from the map the slope of the ground. The utility of this measurement is for the builders of roads and railways, and the user of roads. For the slopes beyond a certain limit cannot be used for certain kinds of traffic. The following table gives an idea of this limit:—

*Maximum Practical slopes for certain purposes**

Slope		Purpose
Degrees	or Gradient	
1°	1/60	Railways.
3°	1/20	First class roads.
26° } 45° }	1/2	Individuals can negotiate with great difficulty.

The slope of the ground is defined as the incline to the horizontal plane. It is expressed either as degrees of an angle made with the horizontal plane, or as gradient which is the rise of so many feet in a horizontal distance. The measurement of the slope is done by means of the clinometer or the level, as pointed out elsewhere in this book. The gradient is computed by dividing the total rise of the ground between two points by the horizontal distance separating them. The total rise is found out from the vertical interval of the contours and the horizontal distance from the scale of the map. The horizontal distance between two points whose gradient is to be calculated is called 'the Horizontal Equivalent'. Thus, the formula for getting the gradient is

$$\frac{\text{V. I.}}{\text{H. E. (in feet)}} = \text{gradient.}$$

For example, if two points A and B are separated on a map by four contour lines drawn at the V. I. of

*Quoted from U. S. Military Services Regulations, Appendix 7.

250 feet, then one point is 1000 feet (250′×4 contours lines) higher than the other. If these points are 1·14 inches apart on a map drawn on the scale of 1 inch to 1 mile, their horizontal distance on the ground must be 2000 yards or 6000 feet. The gradient between them must, therefore, be $\frac{1000}{6000}=\frac{1}{6}$. The gradient is 1 in 6. It must be remembered that the gradient is always expressed with 1 as the numerator. The denominator may thus be with decimals if necessary. For example, a gradient of 6/15 will be expressed as $\frac{1}{2\cdot5}$.

If necessary, gradients can be converted into degrees of the slope angle by multiplying them by 60.* Thus, a gradient $\frac{1}{6}$ will be expressed in degrees as a slope of 10°; ($\frac{1}{6}\times 60=10°$).

Similarly, the degrees of slope can be converted into gradients by dividing them by 60. Thus a slope of 5° has a gradient of ($5°\div 60=\frac{1}{12}$) $\frac{1}{12}$.

Inter-visibility

Mutual visibility between two points or the extent of visible area from a particular observation point can also be determined from the contour map. Visibility between points depends, apart from any intervening features like trees or buildings, upon the slope of the ground separating them. It can, therefore, be found

*The gradient is the tangent of the angle of slope (V.I./H.E.). The tangent of 1° is 1/57·3 or approximately 1/60. Hence, the multiplication by 60. For greater accuracy the multiplication should be done by 57·3.

out from the map whether any two points are intervisible or not by the following methods:—

1. by the examination of the slopes as deduced from the contours on the map;
2. by the comparison of gradients; or
3. by drawing sections of the contours.

(1) It is to be noticed that concave slopes favour intervisibility of points, while convex slopes do not. The points on the valley slopes, which are *concave*, are, therefore *visible* from each other. But the points on the slopes of spurs, which are *convex*, are *not visible* from each other. Uniform slopes also favour visibility.

(2) Another method is to compare the gradients of the two slopes formed from any intervening feature to the two points. If the gradient between the higher point and the intervening feature is steeper, than the gradient between the lower point and the intervening feature or it is the same, the points are intervisible. If, on the other hand, it is gentler than the other gradient, the points are not intervisible.

The following diagrams will help to remember this:—

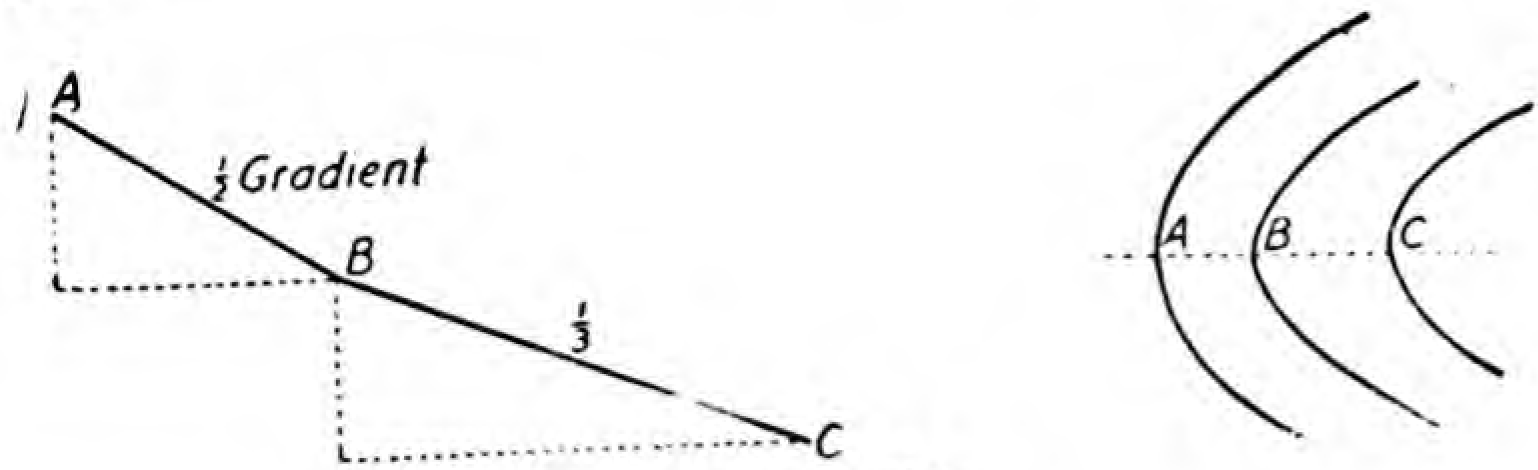


Fig. 36—Visible.

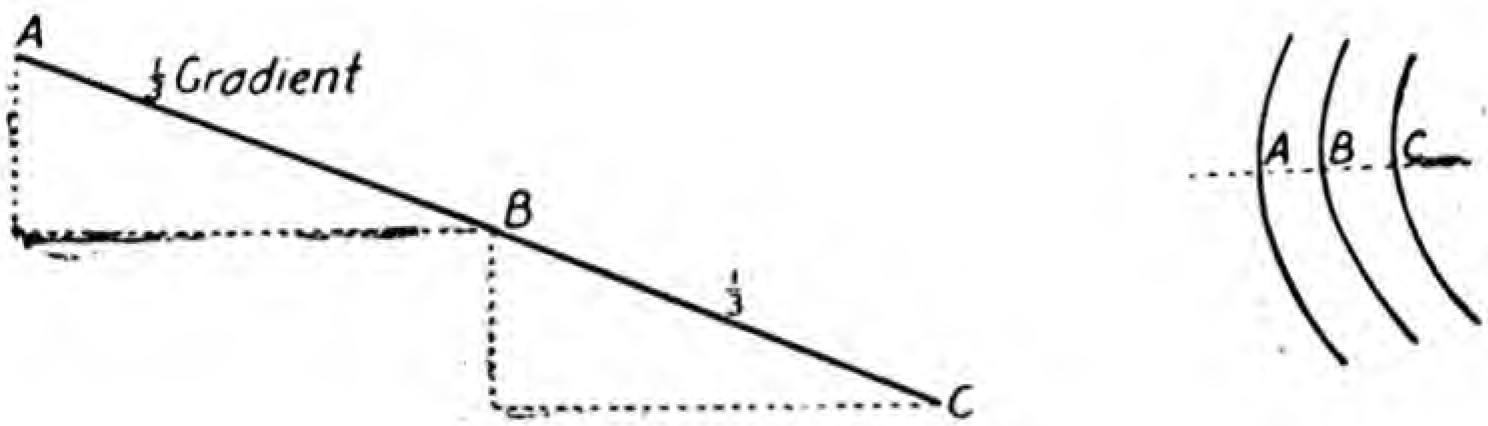


Fig. 37—Visible.

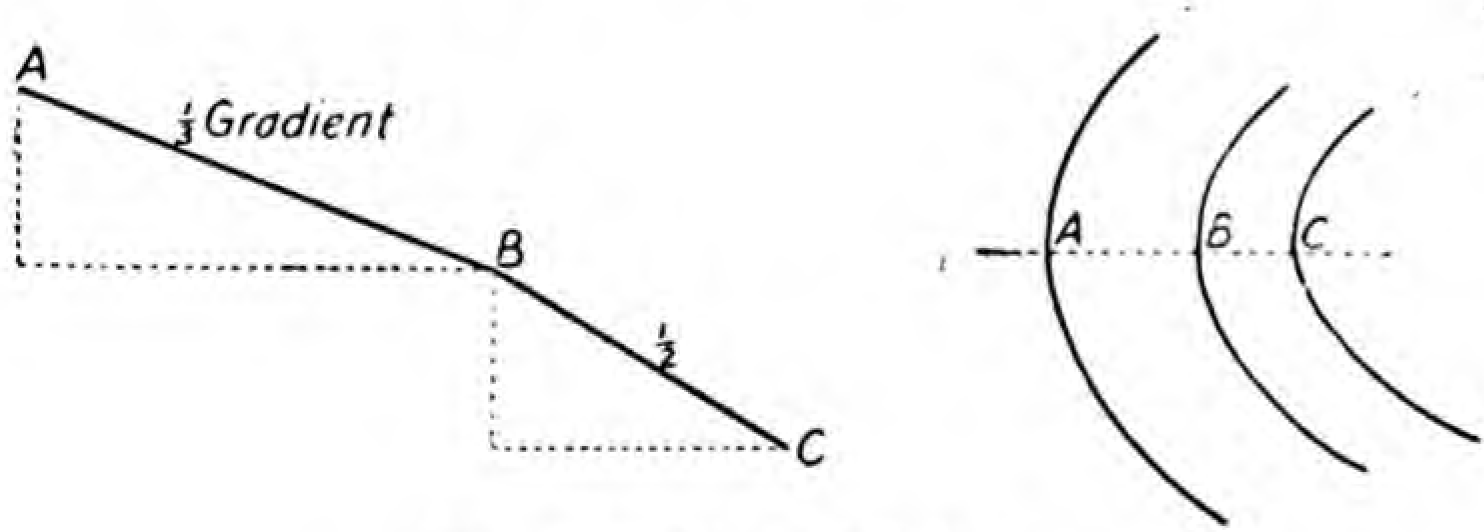


Fig. 38—Not Visible.

A simple arithmetical method of comparing the two gradients between the higher point and the intervening feature and between this latter and the lower point is as follows:—

Distance between the intervening point B and the lower point C is	200 ft.
Distance between A and C is	600 ft.
Difference in height of B and C is	100 ft.
Difference in height of A and C is	200 ft.

Now, in 600 feet the line of sight between C and A rises 200 feet above C. In 200 feet from C and B, therefore, it should rise $\frac{(200\times200)}{600} = 66\frac{1}{2}$ feet.

The line of sight will, therefore, be obstructed, as the intervening feature B rises 100 feet above C. The points A and C are, therefore, not intervisible. These points can be intervisible only when B, the intervening feature, rises above C 66 feet or less.

(3) A section is the outline of the intersection of the ground by a vertical plane. Sections are easily constructed from contour maps to present certain information from them in a more convenient form. They give an excellent idea of the comparative slopes, and also show the extent of the ground that can, or cannot, be seen from a given point. The 'dead ground' is that which cannot be seen from that point. A section is, however, seldom necessary in practice for determining the intervisibility of points. Sometimes, a 'skeleton section' giving the line of sight and the heights of the points and the intervening feature may be enough to decide this problem. Sections may be drawn on the map itself or on a separate piece of paper. A convenient method is given below:—

Take a piece of paper, preferably squared paper for graphs, and place its edge along the straight line

joining the two points on the map for which the section is to be drawn. Mark on the edge of the paper the points where it touches the various contour lines. Then draw, in the middle of the paper, at equal distances straight lines parallel to the edge of the paper. The lowermost of these parallel lines should be the datum line and be marked 0. The lines above it should be marked by the heights of the contours touched by the edge of the paper; starting from the lower heights to higher ones. Now, drop perpendiculars from the points at the edge of the paper where the contour lines meet it. The perpendiculars should be to the corresponding parallel lines representing the various contours. Join the points

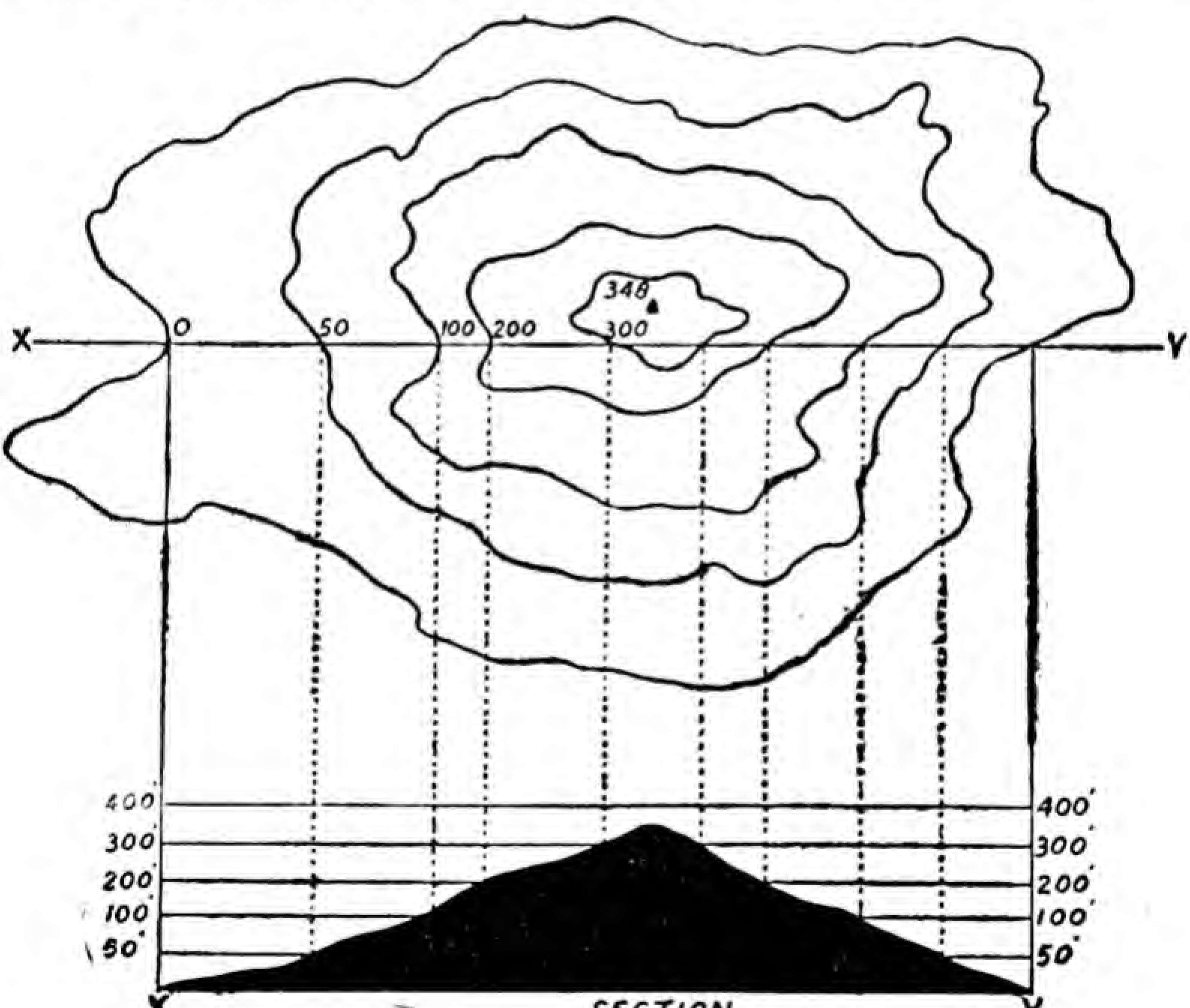


Fig. 39

of intersection between the parallels and these perpendiculars. This gives the required section or profile.

In Fig. 39 a section has been drawn.

Care should be taken in using sections drawn from contour maps. It will be remembered that a number of the intermediate contours are only *interpolated* and not fixed by survey on the ground. Deductions based upon such contours are not, therefore, trustworthy.

For some other methods to determine intervisibiliy between points, the student is referred to 'Exercises in Cartography' by Prof. Debenham.

Hachures

Hachures are lines drawn in the direction in which water would flow down the hill. The slope of the hill is shown by the thickness and spacing of the individual lines. A steep slope is shown by heavy and closely drawn lines. But for gentle slopes they are fine and far apart. Darkly shaded areas, therefore, mark steep slopes and lightly shaded portions gentle slopes. Hachures do not give an accurate idea of the slope, though they give a good general idea of the shape of the ground. They are also a costly method. They also cover up the map and obscure other details in a hilly country. They are, therefore, seldom used in modern maps.

Layering

In modern maps on small scale the area between contours is sometimess coloured by different tints. The lower levels appear with a light tint which deepens with each succeeding level. The chief advantage of layer-

ing is that it enables a quick comparison of the relative heights of widely separated areas on a map. But its chief disadvantage, apart from its cost, is that it may give the impression that the area covered by a particular tint is all level.

Spot Heights

Spot heights show the exact heights of certain spots and are used in combination with all the methods of showing relief.

A comparative study of the above methods leads us to the conclusion that contour lines give exact information about slope and elevation; hachures bring out the ruggedness of the country; and layering by altitude tints emphasises the elevation above sea level.

EXAMPLE IN READING

Sheet No. 63 K/12 (Mirzapur Sheet)
Scale 1 inch to a mile
or 1/63,360

(including parts of Mirzapur and Benares Districts and Benares State.)

The two outstanding features of this map are:—

(i) the Ganges, and
(ii) the Vindhyas.

From many points of view the Ganges is much the more important feature, as most of the area is built up from the alluvium brought down by it. The river flows in a meandering course; in fact, due to the alluvial nature of the plain, all the rivers present in this sheet have a meandering course. There are two loops of the meanders of the Ganges in this sheet, one, the narrower one, to the left and the other, the wider one, to the right. The narrower loop is important, because it centres on Mirzapur, which is the largest town on this map. The map shows that the current of water is always near Mirzapur, so that this part of the bed is never dry. The larger loop to the right is characterised by a very wide bed, in some parts about two miles wide. A large part of this bed consists of dry sand.

Owing to the meandering nature of the river, the banks are shelving in some parts and steep in others. Where the banks are shelving the flood water of the river spreads over large areas in the neighbourhood. But where they are steep the flood waters are contained within them without invading the neighbouring areas.

This is shown by the fact that on the side of the shelving banks, to avoid floods, the villages are situated far away from the river. On the side of the steep bank, on the other hand, they are situated close to the bank.

The Ganges is not bridged at any place in this map. It is a wide river which is very costly to bridge. It has, therefore, been bridged only where traffic justifies it. In this map we notice that there are no large concentrations of population on the other side of the river from which large traffic could come. Mirzapur and Bindhachal are the only towns with large population, but they are both on the same side of the river. So there is no need for a bridge in this area. From November to June the Ganges is crossed by a Pontoon bridge at Mirzapur. There are eight places on the Ganges in this map where there are permanent boat ferries. Three of these places are near Mirzapur, which is natural considering that Mirzapur is the district and the largest town on this map and is, therefore, the focus of the area around it. Considering the number of boats at each ferry place, the most important ferries, outside Mirzapur are those at Bindhachal (connecting it with Harsinghpur) and Bhatauli Ghat (connecting it with Baraini and thence Kachhwa, the largest town on the northside of the river.)

All the tributaries of the Ganges on this map come from the south, from the Vindhyas. Among these tributaries the most important ones are the following:—

(i) Chatar Nadi,

(ii) Kuardari, known in the middle course as Madho Nadi and in the lower course as Khajuri Nadi,

(iii) Harral Nadi. (The famous Tanda Falls are situated on this river in its upper course).
(iv) Ojhala Nadi, joining the Harral near Mirzapur.

Some of these tributaries are dry, except in the rainy season. This is specially true of the Khajuri Nadi. Besides these tributaries there are a number of Nalas which carry the surface drainage when it rains.

Some parts along the tributary rivers are marked by the badly cut up ravine lands. The most extensive area of ravines is found along the Chatar Nadi and the Harral Nadi. The Ganges itself is characteristically free from ravines.

There are also a large number of tanks on this map. All, except two, are, however, small tanks. Some of the tanks are generally dry, except during the rains. There are two tanks, Tandadari Tal and Chandewa Tal, which are very big and have water throughout the year. The significance of the Tandadari Tal is that it supplies water to Mirzapur, situated about nine miles to the north. The water is taken through a pipe line.

The Vindhyas and their foothills occupy about a third of the map in the south. They are a highly dissected plateau, with its steep escarpment facing the south or the east. The plateau is generally about 500 feet in elevation. It descends towards the north in two steps; the first step is about 550 feet above sea level and the second about 350 feet. The descent is very steep, making in some places a slope of about 7°. The Mirzapur—Robertsganj Road, for example, has a slope of about 5° which is considered to be a very steep

slope for a road; the best roads have the *maximum* slope of 3°.

There are a number of flat rounded top hills both on the top of the plateau as well as at its foot. The highest hills are naturally those further south. Thus the Deophulwa to the east of the Robertsganj Road (683 feet) is the highest hill. This hill is a conical hill rising steeply on the top of the plateau. Other hills on the plateau are the Murli (648 feet), the Rajghat (571 feet) and the Bamhandewa (515 feet). The Bamhandewa is characterised by a very extensive and flat top.

Among the foothills the most numerous are those situated in the south-eastern part of the map. The most conspicuous foothills are the Shanker Pawa (549 feet); the Tharpahra (500 feet), being joined by a saddle to another hill 490 feet high; the Kugahi (523 feet). Besides these, there are several low hills further north, the two important examples being the hills near Pahara Railway Station on the Main Line of the E. I. R., and the hills near the Rifle Range to the south of Mirzapur. These latter are only about 300 feet high.

The significance of the foothills lies in their giving rise to stone-quarrying.

The river Valleys on the plateau are broad with steep walls. Note, for example, the Valleys of the Jamthua and its tributary, the Dhaunia. Similarly, the Valleys of the Kuardari and the Harral in their upper courses on the plateau are broad ones.

But as these rivers cross the plateau to reach the Ganges to the north, they have to pass through narrow gorges with steep walls. This is true of almost every

river coming from the south across the plateau. The most significant example is that of the Kuardari which passes through the longest gorge on this map.

Most of the area on this map is shown to be cultivated. The only areas which are not cultivated are on the plateau or in the ravines where the soil is unfit for cultivation. The plateau region and the hills are generally covered by mixed forests. These forests are most extensive in the area to the east of the Mirzapur-Robertsganj Road, and near the Tandadari Tal. The areas that are not covered by forests are covered by grass or scrub. The most extensive areas of this later type are to the west of the Robertsganj Road and in the ravines of the Chatar Nadi.

The area shown on this map is predominantly an agricultural country. It is not an industrial region. The distribution of the population is, therefore, essentially rural; i.e. it is found (*i*) scattered in small villages and (*ii*) is concentrated to some extent only in the market towns which very often happen to be also the administrative towns for the surrounding area. Villages are more numerous in those parts where the soil is fertile than where it is indifferent. Generally, the soil near the plateau is less fertile than near the Ganges, especially to its north. Much larger villages are, therefore, found north of the Ganges than near the plateau. The region near the plateau is marked by small villages.

Mirzapur, being the district town and a great market for the produce of the area around, is naturally the largest town on this map. It is situated on the right bank of the Ganges where the steep banks of the river prevent the flood water from spreading to Mirza-

pur side. The river is also the narrowest in this part, so that it can be easily crossed.

Bindhachal, Khamaria and Kachhwa are the other towns of note. They are all administrative towns, while Khamaria has the distinction of having a carpet factory.

The plateau region is almost without any settled population. The most populated parts in the south are to be found in the wide valleys of the river where agriculture can be carried on. Of these Valleys, the Valleys of the Chatar Nadi and its tributary, the Simaria, are the most important in this respect.

Apart from the hills, there are four areas which are particularly deficient in settled population. These are:—

(i) Area north of Bindhachal;
(ii) Area south of Bindhachal;
(iii) Area north of the Railway line between Pahara and Jhingura stations;
(iv) Area southeast of Kachhwa.

Among these, the areas situated to the north of the Ganges, i.e. (*i*) and (*iv*), are without settled population owing to the danger of floods. Those to the south of the Ganges, i.e. (*ii*) and (*iii*), are infertile.

Mirzapur being the nodal point in this map, most of the lines of communication centre on it. A glance at the map will show that most of the lines of communication are in the western half of the map. This is to be expected from the fact that most of the population of the area is to be found in that part.

It is striking to note that railway communications are deficient in the area represented by this map. This

is to be expected from the absence of many large towns in the area. Mirzapur and Bindachal, the only big towns in the area, are close to each other and lie in the general direction followed by the main line of the East Indian Railway. If Bindhachal had not been in this general direction, it would have been necessary to build a branch line of the railway to connect it to Mirzapur. The existence of the Vindhyas in the south acts as a barrier for any railway line to approach from that direction.

The two railway lines that serve this area are (*i*) the East Indian Railway from Calcutta to Ghaziabad, and (*ii*) the Bengal and North Western Railway from Bhatni to Allahabad. The B.N.W.R. has also a short branch line to connect Mirzapur to the line going to Allahabad. The branch line stops at Mirzapur Ghat without crossing the river. Thus, a generalised picture of the railway communications on this map may be two parallel lines to serve the country on the two sides of the Ganges with a short branch almost connecting them near Mirzapur. It may be of interest to point out that the E. I. R. not only serves Mirzapur directly, but also the numerous quarries that lie near it, to the south of the Ganges. The B.N.W.R., on the other hand, serves the rich agricultural land to the north of the Ganges. A feature of the railway lines on this map is the long stretch of embankments on which they run. There are three stretches of the embankment on the E. I. R., the longest being between Pahara and Mirzapur, and the other two between Mirzapur and Bindhachal. In some cases the embankment is as much as 15 feet above the general level. A similarly long

stretch of embankment marks the branch line of the B.N.W.R. A short stretch of embankment is also to be found on the B.N.W.R. going to Allahabad.

There are some good roads in this area, but, as mentioned above, these are mostly in the western half of the map. There are two first class roads, both running generally north-south. There is no first class road running east-west. The relative distribution of towns is the chief explanation. These first class roads are (*i*) the Great Deccan Road, which comes to Mirzapur only to join the Grand Trunk Road lying to the north of this map, and (*ii*) the Mirzapur-Jaunpur Road which crosses the Grand Trunk Road. The Mirzapur-Jaunpur Road crosses the Ganges at Mirzapur by a Pontoon bridge which is dismantled during the rainy season.

There are a large number of second class metalled roads. They are also mostly in the most thickly populated area, the western half of the map. The most important of these second class roads are those connecting Mirzapur to Bindhachal and Mirzapur to Robertsganj. Several other second class roads have been built to serve the stone quarries in different parts of the map.

The effect of stone quarries on communications in this map is intimate. Thus, the road from Toswa Parsia to the bank of the Ganges is entirely for the benefit of the quarry near Toswa Parsia. For this road passes practically through an uninhabited area. Similarly, the road from Jhingura, on the E. I. R., runs to the Vindhyas, crosses the Robertsganj Road and thence runs along the foot of the plateau and goes finally to Mirzapur by the Great Deccan Road. This road serves

the largest number of quarries on this map.

The railway siding from Pahara, on the E. I. R., is also an example of the influence of stone quarrying on communications. It will be noticed from the map that stone quarries are generally located on the outer skirts of the plateau or on the foothills, which can be made easily accessible.

A number of unmetalled roads are also found on this map. The largest number of these radiate from Kachhwa which is a market town and serves the area far off from Mirzapur. The area near Kachhwa is not only far off from Mirzapur and separated by a wide bed of the Ganges, but is also a rich agricultural land. This can be seen from the large size of the villages.

Other unmetalled roads are a continuation of the second class metalled roads only; e.g. to Pandri Shivgarh or to the Tanda Falls and beyond to Sirsi.

A large number of tracks or footpaths cross the plateau region in all directions to serve the forest area for exploitation.

It is noticed that the areas deficient in population, mentioned above, are also deficient in communication lines.

A minor feature of the map is the presence of a large number of lined wells. These wells abound in thickly populated areas. They, however, disappear from the areas in the neighbourhood of the Ganges, where water for domestic purposes can be drawn from the river, and in the plateau region where it is difficult to dig wells and where there is no settled population.

This map is typical of the Gangetic plain where it borders on the peninsular region of India. It provides

an example of the plateau region as well as of the Gangetic plain. Agriculture, stone quarrying and forestry naturally rule the life of the people in such areas.

Exercises on Scales

1. Construct a plain scale of 4 inches to 1 mile to show divisions of 100 yards and 500 yards.

2. Construct a plain scale for 1 inch to 1 mile showing suitable divisions in yards.

3. Construct a plain scale of 2 miles to 1 inch, showing subdivisions into furlongs.

4. Construct a plain scale of 16 miles to 1 inch, showing quarter miles.

5. Construct a scale of 1/100,000 to show quarter miles.

6. Construct a scale of 1/20,000 to show yards. Also add a scale of paces (standard pace of 30").

7. Construct a time scale for marching at 3 miles an hour for a map on the scale of 1/100,000.

8. Two bridges are exactly 3 miles distant from each other. On the map of the area they are shown to be 7·5 inches apart. Construct a graphical scale and also give the R. F. of the map.

9. Construct a time and distance scale for an aeroplane travelling at 120 miles per hour, using a map on the scale of 1/1,000,000 (1/M).

10. Which is on a larger scale: the 1 inch Survey of India map, or the French 1/50,000 map, or the German 1/80,000 map?

11. Construct a scale of slopes for a map on 1/21,120 with a V. I. of 20 feet to show slopes upto 5°.

Exercises on Map Reading

1. Comment on the different methods by which relief is shown on the topographical maps.

2. What is a contour line? Distinguish it from a form line. On what principle is the contour line based?

3. How is relief on a map shown by the contour line? Show by contours the following:—

   (*a*) Spur, (*b*) Valley, (*c*) Watershed, (*d*) Hill, (*e*) Underfeature.

4. Define 'slope'. Classify slopes and show each class of slope by contour lines, adding sections under the contours for each slope.

5. What is gradient? How is it calculated? How will you convert a gradient into a slope in degrees of angle? Give an example.

6. How will you determine the intervisibility between two points with the help of a contour map? Illustrate by examples.

7. What is a section? What are its uses? Draw an imaginary section illustrating the whole process.

8. Convert the following gradients into degrees of slopes:—

   1/5, 1/12, $\frac{1}{15}$, $\frac{1}{20}$, and $\frac{1}{30}$.

9. Convert the following degrees of slope into gradients:—

   5°, 6°, 10°, and 15°.

10. On the Mirzapur sheet of the Survey of India map (63 $\frac{K}{12}$), calculate the gradient of the road near Tanda Falls.

CHAPTER III

MAP PROJECTIONS

The earth is a sphere and, therefore, the only true representation of it is the globe. For practical purposes, however, the globe is useless, as any globe made on a large scale is too big to handle. If the globe were to be made on the scale of the International or the 'Millionth map' (1/M, about 15·8 miles to the inch; not a very large scale) its diameter will have to be approximately 42 feet! How many of us can carry a globe of this dimension? Besides this difficulty of handling large globes, which alone can be of practical use; distances cannot be measured conveniently nor different regions compared on the globe. On account of these difficulties, for practical purposes the globe has to be discarded. Some methods for representing the sphere (the shape of the earth) on a plane surface (the flat map) have, therefore, to be found out. These methods are the map projections.

The word 'projection' here has been derived from geometry meaning that a particular geometrical shape is 'projected', with the help of light as in a cinema, by throwing its shadow on a flat surface. In this way, certain outlines are obtained on the flat surface. The character of these outlines naturally depends upon the position of the light in relation to the body to be pro-

jected. The projection may not be made sometimes directly on a flat surface, but on another geometrical figure which has a '*developable surface*', like that of a cone or a cylinder. A 'developable surface' is one that can be spread flat by cutting open. Fig. 40 shows two

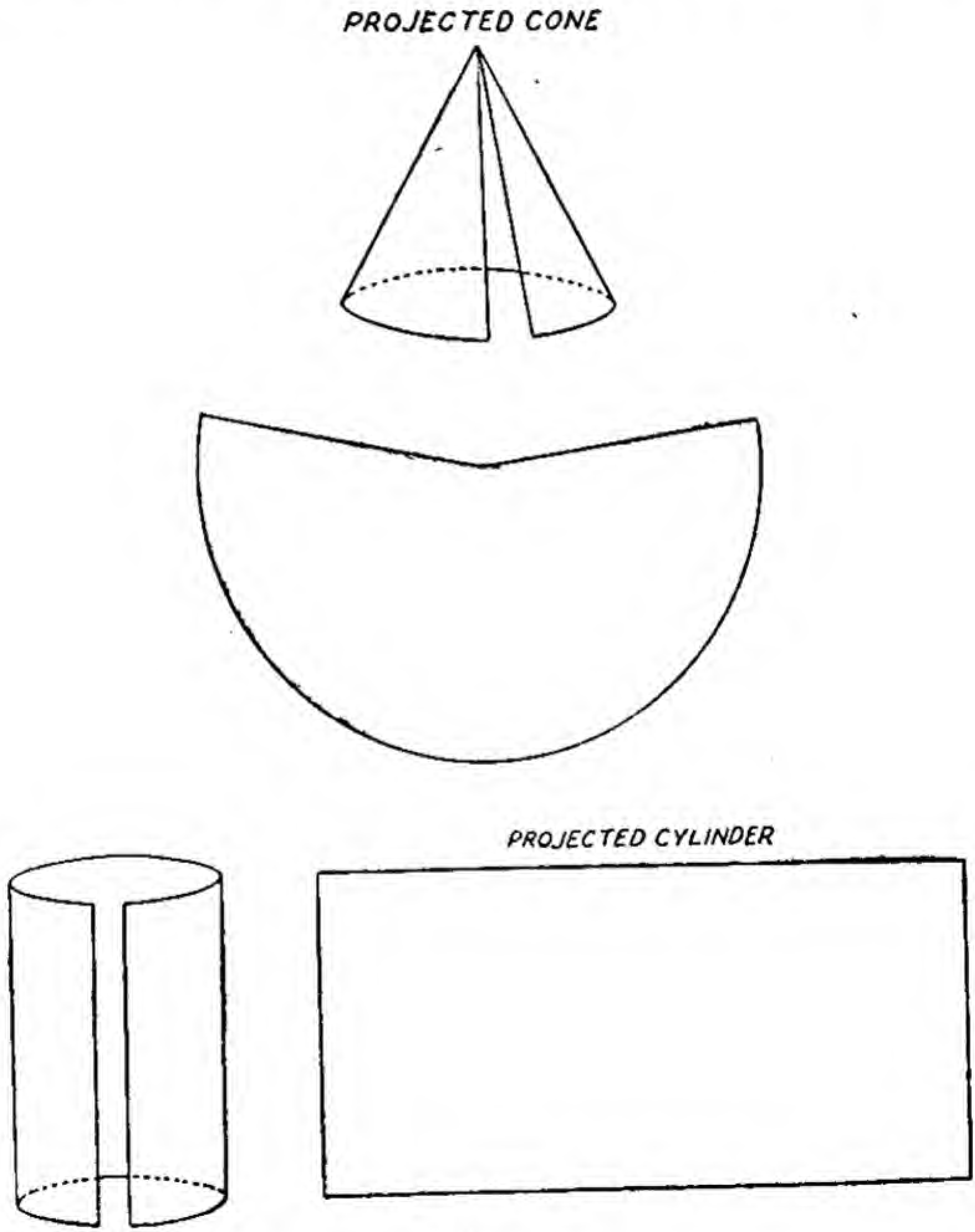


Fig. 40

such surfaces, the cone and the cylinder.

In order to remove some of the defects in the outlines, or the shadow picture, that may be thrown on the plane surface by the above method, help is taken from mathematical calculations about the earth. Thus, the 'geometrical projection' has always to be *modified* by 'mathematical projection' to give a satisfactory result. In practice, therefore, the globe is *never projected with the help of light to produce the network of a map.* The network is drawn by the help of mathematical tables.

It must be remembered that the object of a map projection is to transfer the lines of latitude and longitude from the round globe to the flat map. It must be realised that this cannot be done without distortion; for the surface of a sphere cannot be spread out on a plane without stretching or tearing. Some form of a compromise has, therefore, to be followed by map projections. This means that if in one part of the map the lines of latitude and longitude are so drawn as to correspond to those on the globe, in another part of the map they are far from this correspondence.

A map projection is defined "as a systematic drawing of lines representing meridians and parallels on a plane surface, either for the whole earth or part of it,"* on which a map for a particular purpose can be drawn.

There can be hundreds of map projections or methods of drawing the network of the lines of latitude and longitude, every one having a special feature of its own. It is not quite accurate, therefore, to *classify* map projections. But from the student's point

*Elements of Map Projection by Deetz and Adams.

of view classification always helps understanding.

There are generally two types of classifications of map projections; the first type is based on the *purpose* for which the map projection is best suited, and the second type is based on the method of *construction* of the map projection.

The first type divides the map projections into the following classes:—

(i) *Equal Area* or the Homolographic projections. This class of projections shows correctly the areas of the earth on the map. The scale on this projection is true in all directions.

(ii) True shape or the *Orthomorphic* projections. [This class is also known as conformal Projections.] The outlines of countries are accurately shown on this projection. In order to achieve this, however, the scale is changed constantly. But the angles at which the meridians cut the parallels are everywhere right angles on this projection.

(iii) True Direction or the *Azimuthal* projections. The special feature of these projections is that the azimuth; that is, the directions of all points on the map as seen from a central point on it are the same as the corresponding directions on the surface of the earth. It must be remembered that the directions are true only between the central point and those seen from it; they are not necessarily true between other points.

The second type of classification divides projections into the following classes:—

(i) *Zenithal projections.* The method of their construction is derived from the supposition that a part of the globe is 'projected' on a tangent plane.

This class is further subdivided into two classes:—

(*a*) according to the point where the tangent plane is supposed to touch the globe; i.e. at the *pole,* the *equator* or any *other point.* This gives the three classes in the same order:—

1. The Polar Zenithal;
2. The Equatorial Zenithal;
3. The Oblique Zenithal.

(*b*) according to the position from which the light is supposed to be thrown, i.e. from the *centre* of the globe, the *diameter* of the globe or from beyond the globe, at *infinity.*

This gives the three classes in the same order:—

1. Gnomonic;
2. Stereographic;
3. Orthographic.

(ii) *Conical projections.* The method of their construction is derived from the supposition that a certain part of the globe is projected on to the surface of a cone that is put round it. The cone is then supposed to be cut open and spread flat like a plane. The part of the globe which the enveloping cone

is supposed to touch gives the starting point in the construction of the projection. The line along which the cone is supposed to touch the globe is called the STANDARD PARALLEL. The line along which the cone is supposed to be cut open from the base to the apex is called the CENTRAL MERIDIAN.

(iii) *Cylindrical projections.* When the globe is supposed to be covered by a cylinder, instead of a cone, the projection derived is a cylindrical projection.

(iv) *Conventional projections.* When the construction of a projection is derived analytically, not based on the 'projection' of the globe on a plane, a cone, or a cylinder it gives a conventional projection.

In discussing the construction and utility of some of the most common projections in use, we shall follow the second classification given above.

In order to grasp thoroughly the graphical construction of projections as described in the following pages, it is important to realise that a circle representing the earth on the selected scale is the first step. This circle gives the measurements for subsequent steps. These measurements are the following:—

(i) Radius of the standard parallel;

(ii) Spacing of the parallels, for dividing the central meridian;

(iii) Spacing of the meridians, for dividing the standard parallel.

To draw the above circle at the desired scale it is

convenient to remember that the radius of the earth is about 250 million inches (25 crore inches) and there are 63,360 inches in one mile.

ZENITHAL PROJECTIONS

Among the zenithal projections the most commonly used is the Gnomonic. The stereographic and the orthographic projections of this class were also common until recently. They have been, more or less, discarded now.

GNOMONIC PROJECTION

When a plane is supposed to touch the globe at a point and the light is thrown from the centre, the projection that results is described as Gnomonic Projection. The most important properties of this projection are:—

(i) All Great Circles are represented by straight lines on this projection. A straight line drawn between any two points on a chart on this projection represents, therefore, the shortest distance or the most direct route between them.

(ii) All azimuths or directions from the centre of the map on this projection are correct.

(iii) In the case of the Polar Gnomonic Projection, (i.e. when the pole is the centre of the map) the meridians are straight lines radiating from the centre, and the parallels are concentric circles. In the case of the Equatorial Gnomonic, the parallels are curves except the equator which is a straight line.

(iv) The concentric circles representing the parallels become wider apart as the distance from the pole or the centre of the map increases. This causes the scale of the map to be greatly exaggerated towards the outer boundaries of the map. This exaggeration increases more rapidly in the case of the meridians than in the case of the parallels. Thus, in the case of the Polar Gnomonic, for example, the scale exaggeration is as follows:—

	Latitude scale	Longitude scale
At 80° Lat.	3 p.c.	1·15 p.c.
„ 60° „	33 „	15·4 „

Owing to this exaggeration of scale outwards, places near the boundary of the map become greatly distorted in distances, areas and shapes.

(v) This projection cannot be used for making the map of a complete hemisphere, as the lines drawn for projecting points 90° distant from the centre of the map become parallel to the plane of projection. Such lines, therefore, can never touch the plane of projection on which the map is to be drawn.

(vi) It requires a good deal of computation and its construction is difficult, except in the polar case.

To construct the Polar Gnomonic Projection, choose the scale on which the map is to be drawn. With that scale as the radius, draw a circle. From the centre

4

of this circle, starting from the side of the polar axis, draw radii at angles which are *complements* of those of the latitudes desired to be shown. Thus, if the latitudes to be shown are 80°, 70°, 60°, and 50°. Then the radii will be drawn at the angles of 10°, 20°, 30°, and 40°; all these angles being complementary to those of the latitudes. If desired, the radii can be drawn at the angles representing the latitudes, but the angles in this case will have to be measured from the side of the equator and not from the side of the polar axis.

Produce these radii to meet a straight line drawn tangent to the pole on this circle.

With this pole as the centre and the distances marked by the produced radii as radius, draw semicircles to represent the latitudes.

From this centre lay off the required longitudes with the help of a protractor.

Rub off the first circle and its radii and complete the circles of the projection.

In Fig. 41 we select a scale of 1/160,000,000 or 1 inch is equal roughly to 2525 miles. On this scale the radius of the earth will be represented by about 1·56 inch. With this radius, therefore, we describe the circle QPR from the centre O. We decide to show on the projection the latitudes of 80°, 70°, 60° and 50°. We draw radii, therefore, from O making with the polar axis the angles of 10°, 20°, 30° and 40°. Now, we produce them to touch the tangent plane TT′ at A, B, C, and D. With P as the centre and PA, PB, PC and PD respectively as radii, draw semicircles representing the latitudes of 80°, 70°, and 60° etc. From the centre P lay off the longitudes with the help of the

protractor, taking care to mark the tangent line as the 90° East and West longitude and the perpendicular

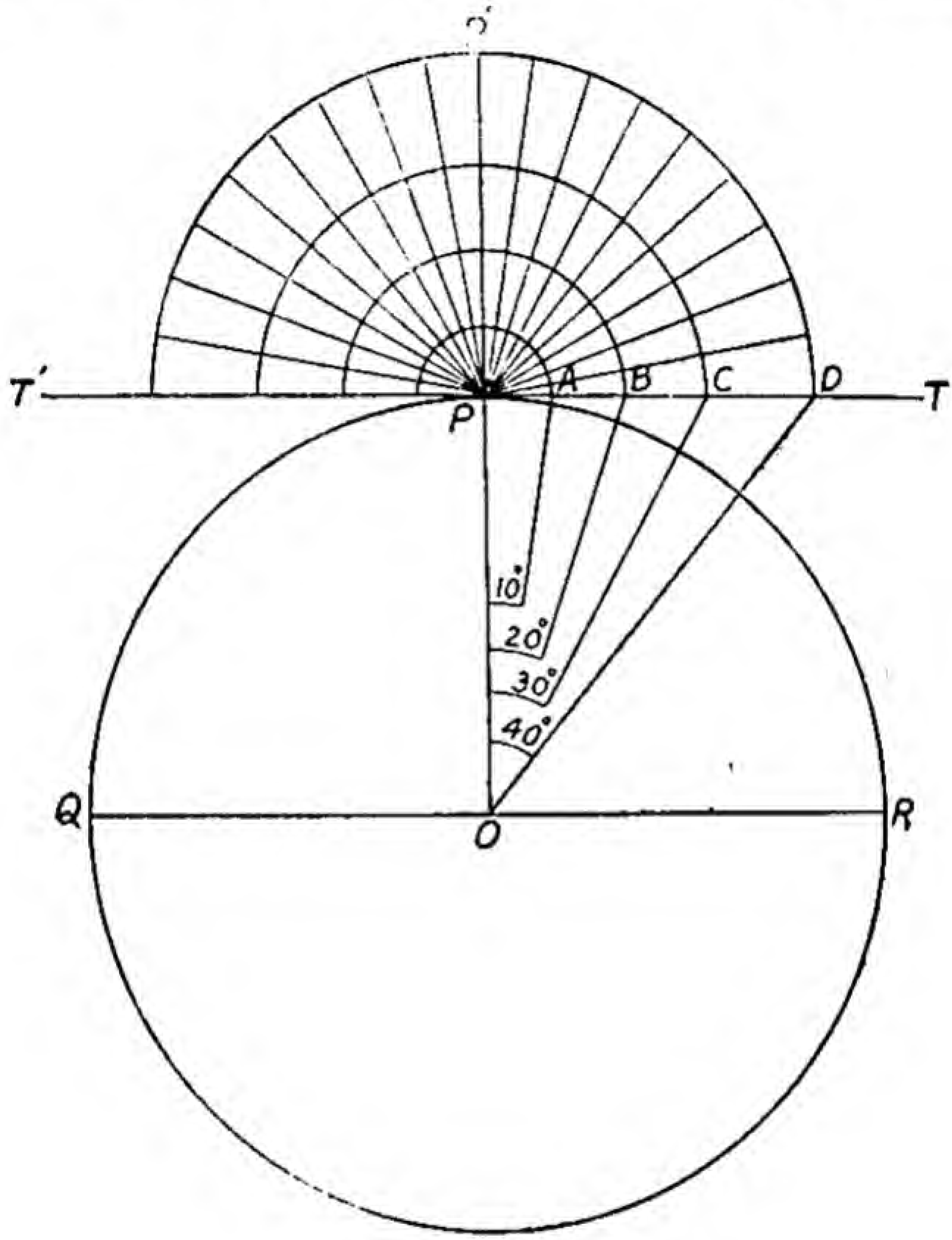


Fig. 41

(PP' in the diagram) as the 180° and 0° (Greenwich) longitudes. The completed projection will appear as shown in fig. 42.

The chief use of the Gnomonic Projection is to produce supplementary charts for the Mercator Projection sailing charts. To facilitate sailing by the great

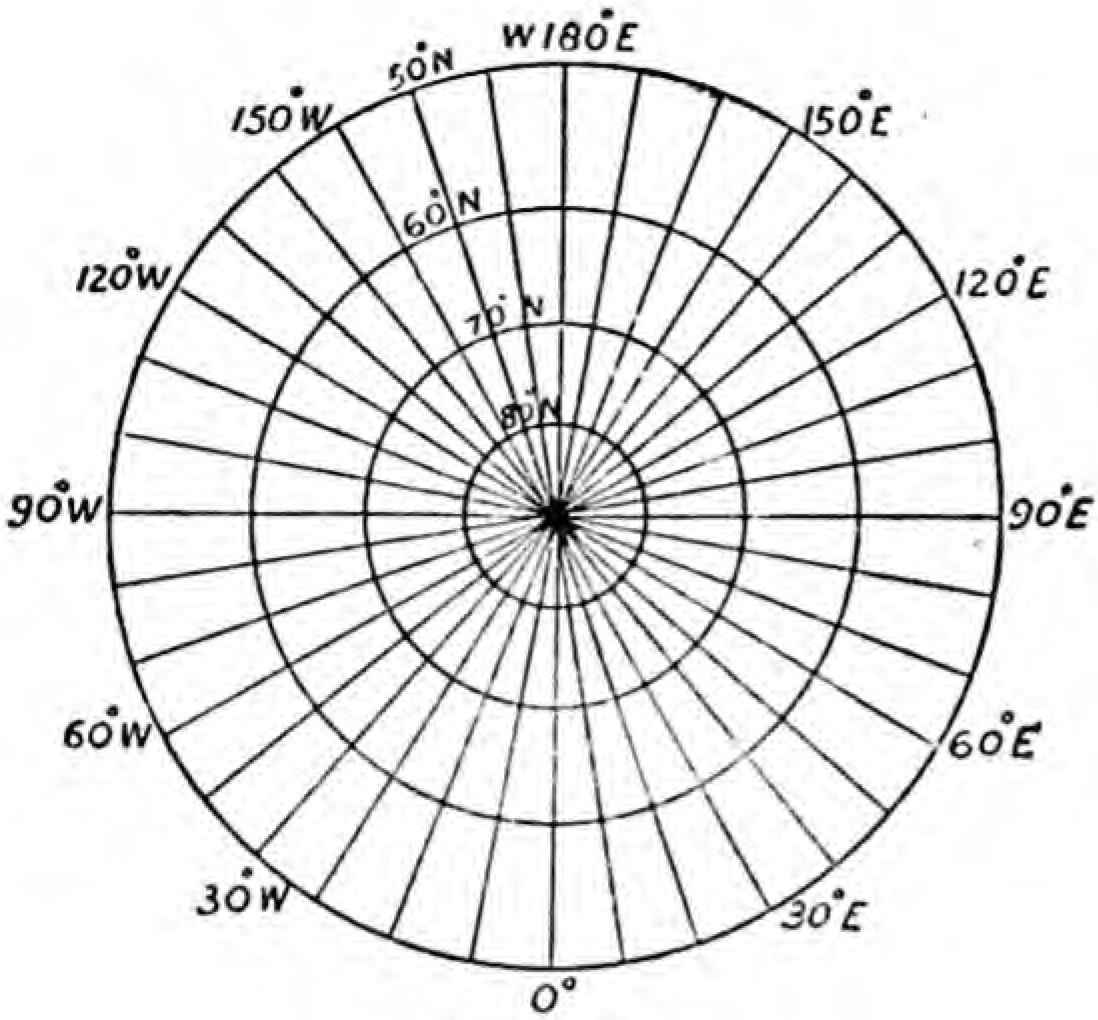


Fig. 42

circle routes, the governments of the United States of America and Great Britain have published Gnomonic Charts covering in single sheets the North Atlantic, the South Atlantic, the Pacific, the North Pacific, the South Pacific, and the Indian Ocean.

The projection is also being used for the plans of harbours and polar charts.

The charts of the sky showing stars are also prepared on this projection.

Owing to the great exaggeration this projection is seldom used for Atlas maps.

Conical Projections

The conical projections include some of the most commonly used projections. The popularity of this group of projections among cartographers is shown by

the fact that the atlas maps are drawn mostly on one or the other projection of this group. This popularity is due not only to the simplicity of construction and relative accuracy of the conical projections, but also because a map drawn on such projections can be divided into sections which can be printed on different pages of the atlas. The importance of the conical projections is illustrated also by the fact that a projection of this group has been chosen for the International Map (Scale 1/M) of the world. It must be remembered that the greatest difficulty of selecting a suitable projection is in the maping of the middle latitudes. It is for these latitudes that the conical projections, as a group, are the best.

It is important to note here that most of the conical projections are determined analytically and, therefore, are not 'projections' in the strict sense of the word. The elements of such projections are given by mathematical formulae rather than by 'projection' or the shadow picture of the globe.

The most important projections of this class are:—

(i) Simple Conical Projection;

(ii) Simple Conical Projection with two standard Parallels;

(iii) Bonne Projection;

(iv) Polyconic Projection;

(v) Sanson-Flamsteed or Sinusoidal Projection;

(vi) Lambert Conformal Conical Projection;

(vii) Albers Projection.

Simple Conical Projection

(With one standard parallel)

In the simple conical projection the cone is supposed to be vertically above the pole. The standard parallel marks the part of the globe along which the cone touches it. This projection is never used in its true geometrical form, owing to the uneven spacing of the parallels in the original form. In practice, the spacing of the parallels is modified mathematically so that they are drawn evenly at their true distances.

The properties of the simple conical projection are that:—

(i) the meridians are straight lines radiating from a point.

(ii) the parallels are concentric curves drawn at true intervals determined mathematically.

(iii) the scale is true only along the standard parallel. The scale is greatly exaggerated, however, as one moves away from this standard parallel. This is specially true east and west of the central meridian. North and south of the standard parallel the scale is rendered true because of modification by mathematical formula.

(iv) the area is shown correctly only in a narrow strip along the standard parallel. This projection is not, therefore, an equal area projection.

(v) Owing to the change of scale, the projection is also not a conformal projection.

The construction of this projection is simple. The

graphical method described here gives an approximately accurate projection. The circle drawn here gives the measurements for spacing the meridians and the parallels.

To construct the projection, describe a circle on the required scale (say 1/160 million which gives a radius of 1·56 inch). Select the standard parallel, say 30° N.

In the following diagram, the circle EPQ repre-

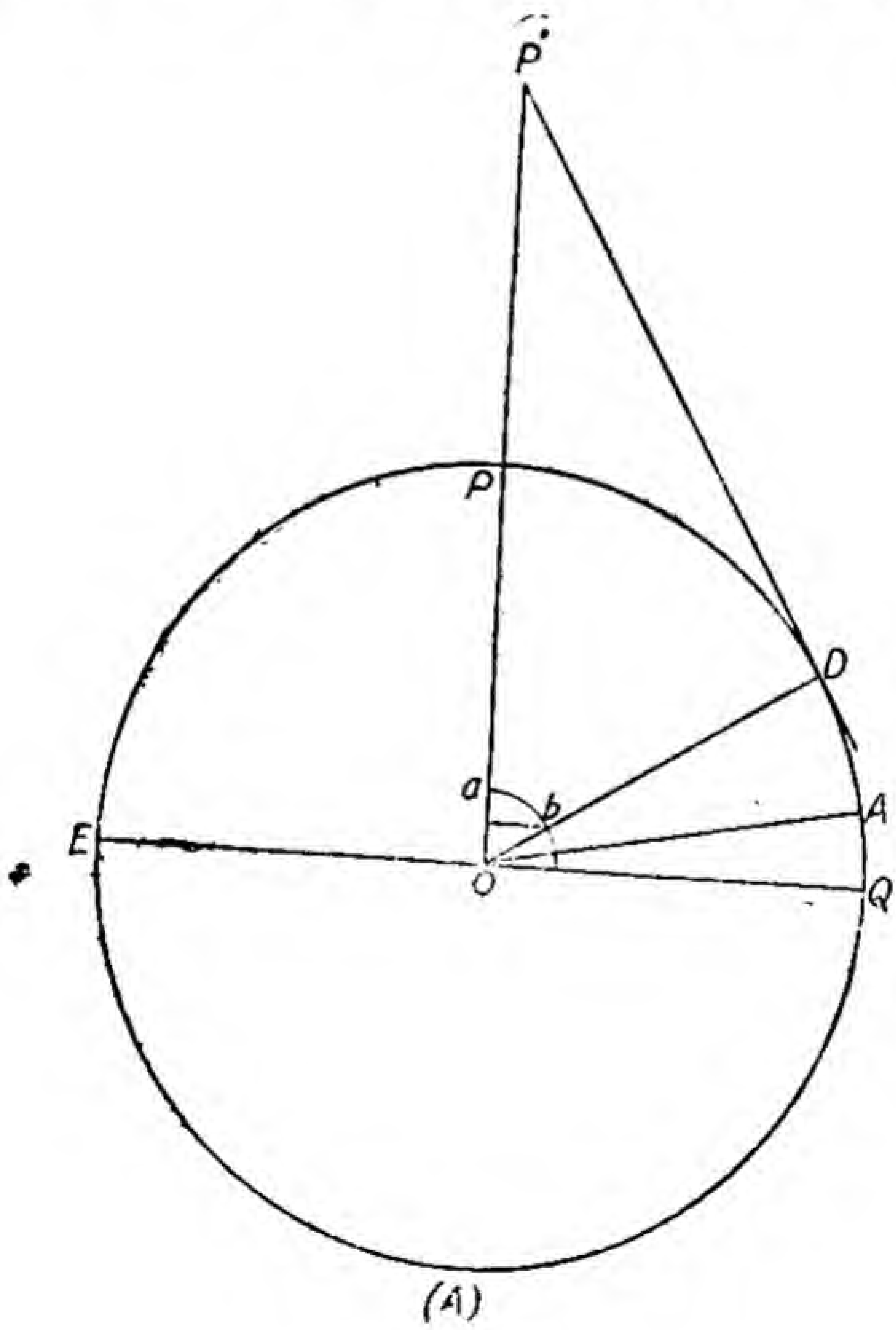
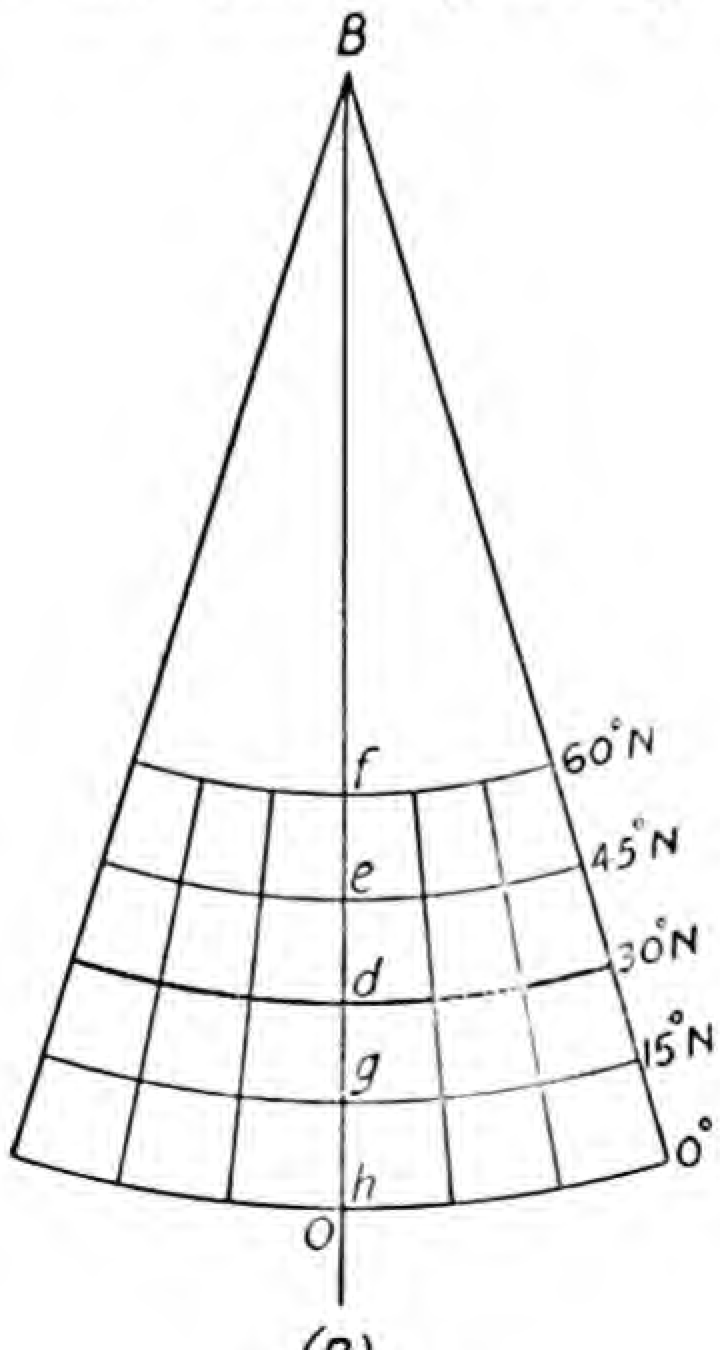


Fig. 43

sents the globe, P the pole, and EOQ the equator. At the centre O make an angle of 30° by the radius OD. D marks the point where the standard parallel crosses the circle. At the point D draw a tangent P′D meeting the polar axis produced at P′. Mark off on the circle as shown, the radius OA fixing the interval at which the parallels are to be shown on the projection. With QA as radius and O as centre describe a semicircle cutting OD in b. From b draw a line parallel to the equator to meet the polar axis in a. Then ab is the measurement for dividing the standard parallel for drawing the longitudes on the projection.

Now, draw BO (as in fig. 44 B) to represent the



(B)

Fig. 44

central meridian. Then, with B as the centre and P'D as radius draw the standard parallel of 30° as a curve, cutting the central meridian in d. Take the distance QA and mark with it equidistant points above and below d on the central meridian.

With B as the centre, as before, and radii Be, Bf, Bg and Bh draw the other parallels on both sides of the standard parallel.

Now, take the distance ab from the circle and divide the standard parallel. Through these points of division, draw meridians as straight lines converging on B. This completes the projection as shown in the diagram (44 B) above.

The chief use of this projection is for making maps of relatively small areas with little latitudinal extent; like Denmark, Poland and Eire (Ireland).

SIMPLE CONICAL PROJECTION

(*With two standard parallels*)

This is a further improvement on the simple conical projection with one standard parallel only. The improvement lies in selecting two standard parallels for division true to scale. It enables a wider extent of latitude to be shown in this way, and removes, therefore, the main handicap of the simple conical projection with one standard parallel, which suits only the narrow extent of latitude.

The properties of this projection are practically the same as of the simple conical projection with one standard parallel. But owing to the selection of two standard parallels, there is a greater amount of accu-

racy in this projection. This projection is sometimes called the 'Secant Conic Projection', because to get two standard parallels the cone of projection has to be supposed to cut into the globe rather than cover it. There is, however, a separate secant conic projection which is entirely different from this projection.

The main problem involved in the construction of this projection is to find the radii of the two standard parallels. The rest of the construction is similar to that of the simple conical projection.

Describe a circle to represent the globe on the required scale as shown in the following diagrams. Draw the equator QQ′ and the axis OP. Select the

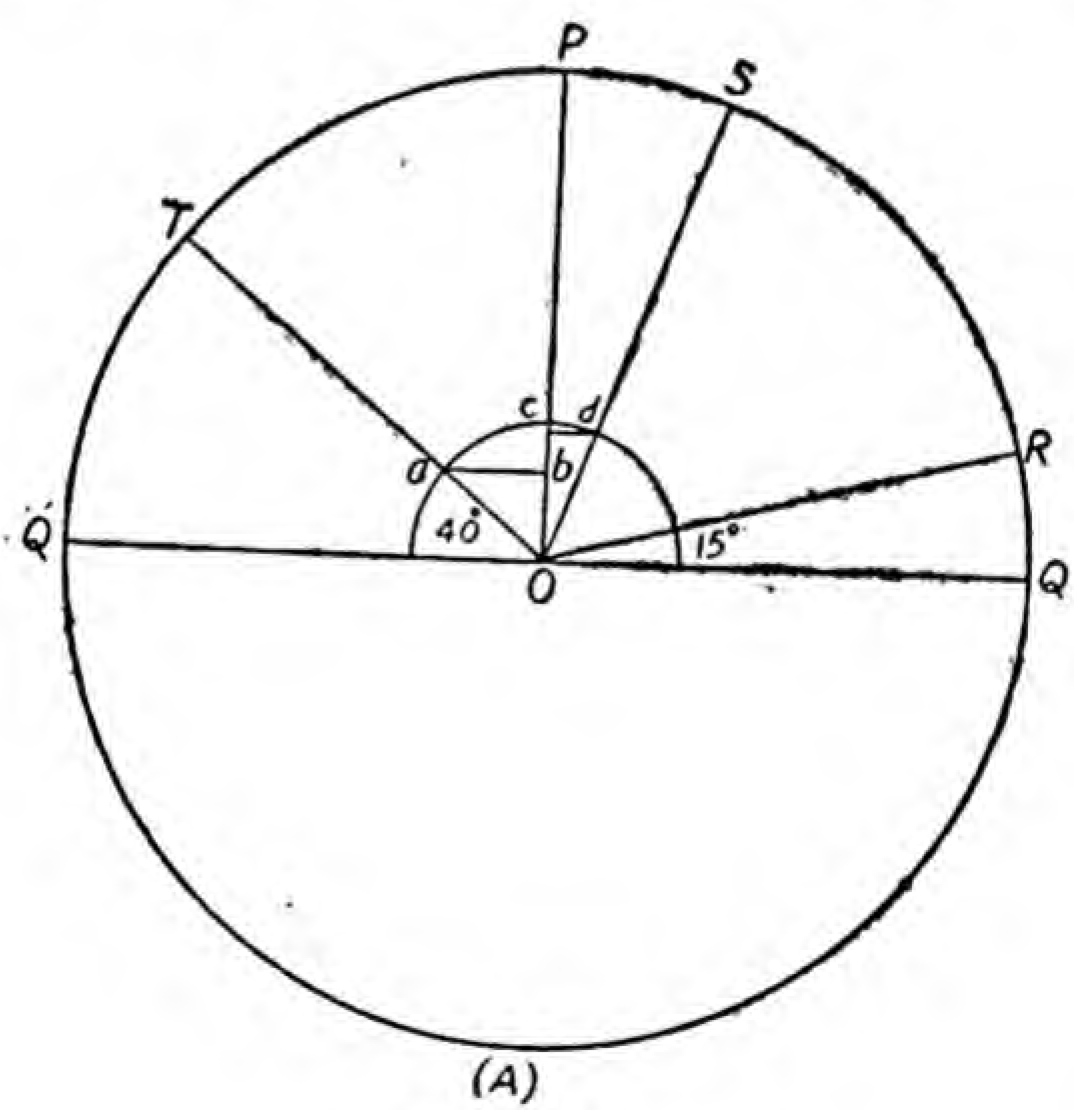


Fig. 45

standard parallels, 40° and 70°. Draw radii OT and OS to mark on the circle the positions of the standard

parallels, 40° and 70°, respectively. Draw also OR to mark the angle of the intervals at which the parallels are to be shown.

With QR as radius and O as the centre, describe a semicircle. Where this semicircle cuts OS and OT, the radii of the standard parallels, from there drop perpendiculars ab and cd to the axis OP. The distances ab and cd give the spacings of the meridians at the standard parallels of 40° and 70° respectively.

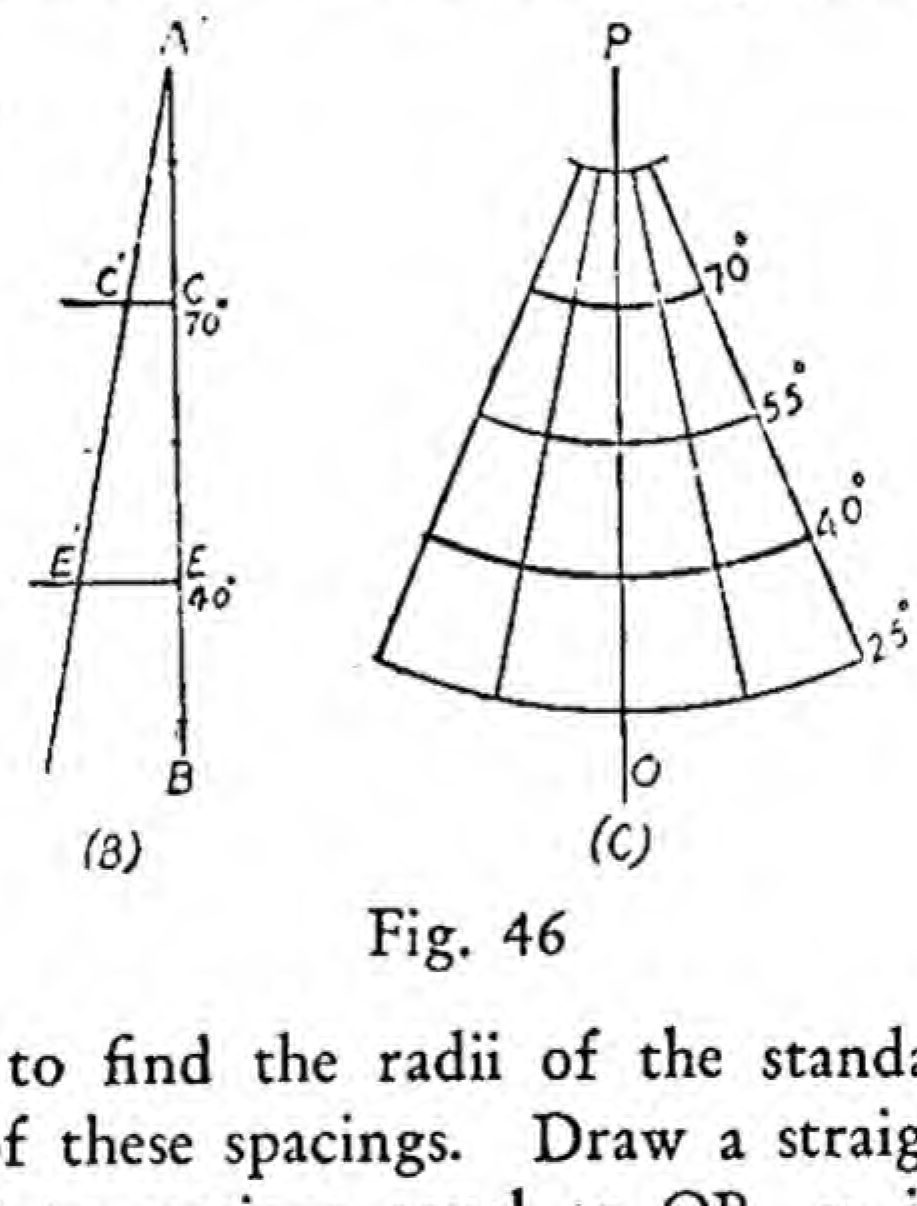


Fig. 46

Now, to find the radii of the standard parallels make use of these spacings. Draw a straight line AB. Divide it into sections equal to QR, as in fig. (B). From C and E on this line erect perpendiculars CC′ and EE′ equal to cd and ab spacings respectively for 70° and 40°. Through the points E′ and C′ draw a straight line to meet AB in A. Then, AC′ and AE′ give the radii of the standard parallels 70° and 40° respectively.

The difference between the standard parallels is

30°, which is represented here by the distance CE on the straight line AB. We have decided to show the parallels at the interval of 15°. The distance CE will, therefore, be divided into two equal parts. An equal distance will be marked above C and below E. Thus, AB, AD, and AF give the radii of the other parallels to be shown on the projection.

We can now draw the projection, as shown in the diagram (C) above with P′ as the centre for drawing the parallels. Draw the meridians as straight lines through the points of division on the standard parallels.

The standard parallels should be so selected as to cover two-thirds of the height of the map. This gives the best results.

This projection is neither an equal-area projection nor entirely orthomorphic. It is, however, good for drawing the atlas maps of Europe, Russia, and Scandinavia etc. Asia is too big for it.

Bonne Projection

The Bonne Projection owes its name to its author, a French cartographer, Rigobert Bonne (1727-1795). The main points in which it differs from the conical projections described above are:—

(a) standard meridian (central meridian), divided true to scale, and

(b) all parallels divided truly like the standard parallel. The east-west exaggeration of the scale common to the above conical projections is thus removed to some extent.

The Bonne Projection has been very popular, especially in France, chiefly because of the advantage of

its being an equal-area projection. It has, however, fallen from grace recently in France, owing to the great distortion towards the margins of the map. On account of this distortion, distances measured near the margins of the map are not accurate. This inaccuracy of distances was the cause of great inconvenience during the war of 1914-18 in military operations. It is being replaced in France by the Lambert equal-area projection.

The properties of this projection are:—

(i) It has a fixed central meridian and a selected standard parallel, both divided true to scale.

(ii) The parallels are concentric curves at true distances and divided for meridians true to scale.

(iii) Except the central meridian, which is straight, all the meridians are curves; the curvature increasing towards the margins of the map.

(iv) Every small quadrangle in this projection has both its base and height true to scale. The projection is, therefore, equal-area projection.

(v) As the parallels and the meridians in this projection do not cut at right angles it is not a conformal projection. Shapes are accurate only along the central meridian.

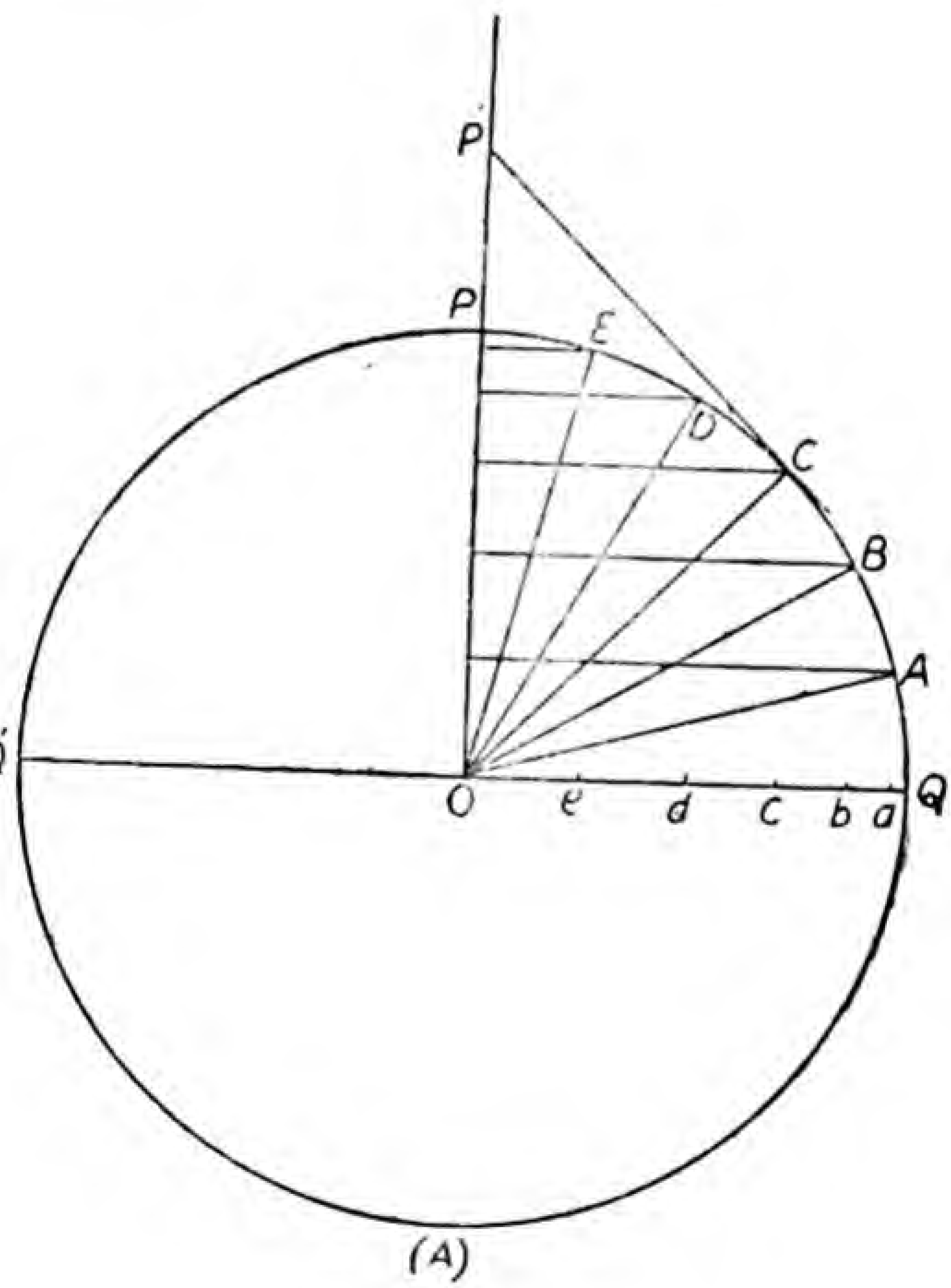
The construction of the Bonne Projection is very similar to that of the two conical Projections described above.

Describe a circle on the scale selected. Draw the equator, QQ′ as in Fig. 47 A, and draw the axis OP,

producing it to P′.

Select the standard parallel, say 45°N. Draw the radius OC to mark its position on the circle at C. From C draw the tangent to meet OP produced in P′. Then P′C gives the radius of the standard parallel of 45°N.

Mark on the circle the positions of the other parallels by the radii OA, OB, OD and OE. From A, B, C, D and E draw lines parallel to the equator to meet the axis OP.



(A)

Fig. 47

Mark the lengths of these parallels along the equator respectively as Oa, Ob, Oc, Od and Oe. Then

the sections ab, bc, cd, de and eo give the divisions for the 75°, 60°, 45°, 30° and 15° parallels respectively.

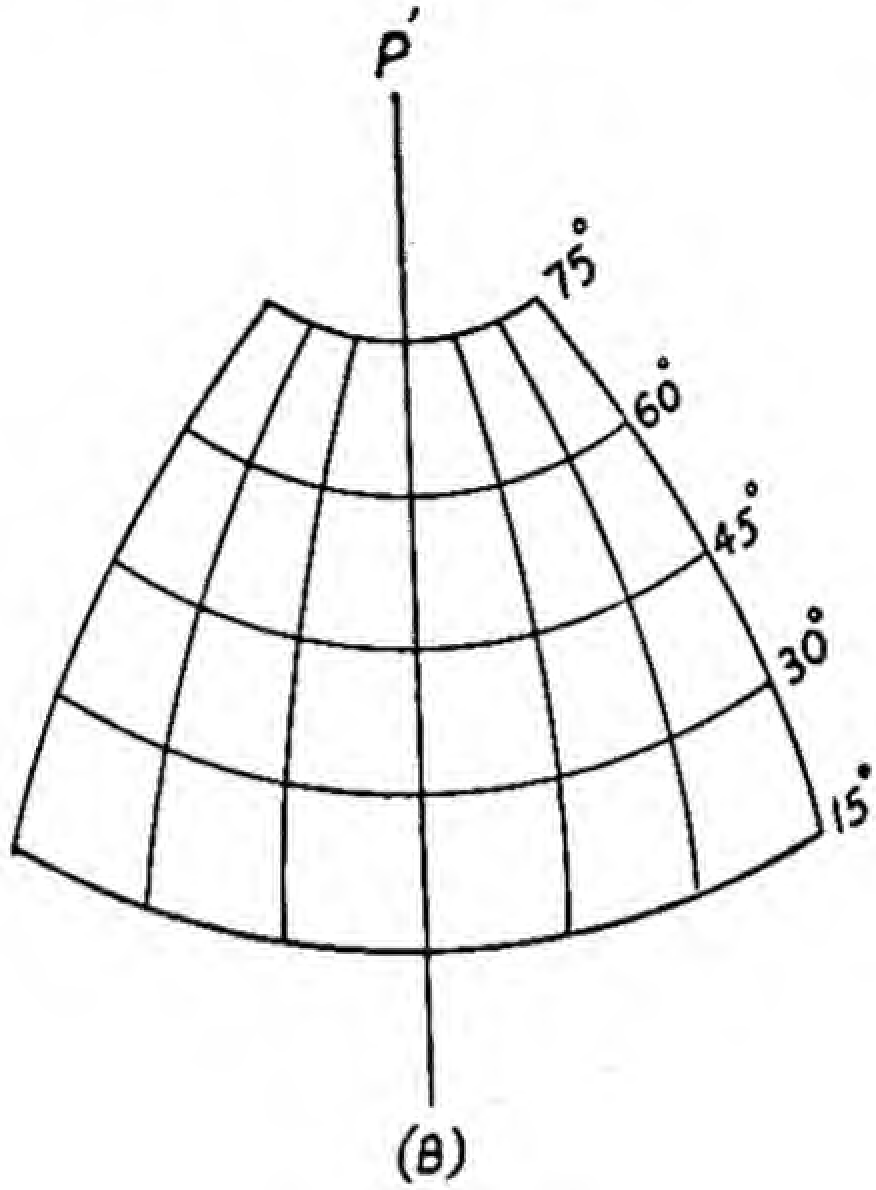


Fig. 48

With the measurements thus obtained, draw the projection as shown in Fig. 48 B. Draw a straight line to represent the central meridian. With P′ on this line as the centre and P′C, the tangent on the circle, as the radius draw the standard parallel of 45°. Now, divide the central meridian, both above and below the standard parallel, into parts equal to the distance QA on the circle. With P′ as the centre draw parallels through these points of division. Then, divide each parallel according to the distances obtained along the equator; i.e. ab, bc, etc. in fig. 47 above. Through these points of division on the parallels draw curves to

represent meridians.

It will be noted that the curvature of the parallels on this projection will be determined largely by the standard parallel selected. The curvature is greater if a higher latitude is selected as standard parallel than if a lower latitude is so selected.

The Bonne Projection is good for any extent of *longitude* and suits most, therefore, the maps of Trans-Continental Railways, like the Trans-Siberian Railway.

It is used mostly for atlas maps of countries, especially for those which are sufficiently compact to avoid distortion at corners. Maps of Europe, Asia, and Australia etc. are made on this projection for atlases. But on account of its great extent Asia is not well shown on this projection.

The Bonne projection has also been used for survey maps of small areas in Scotland and Ireland. Belgium, Holland and Switzerland also use this projection for survey maps.

SANSON-FLAMSTEED OR SINUSOIDAL PROJECTION

This projection makes use of sine curves which are like the rising and falling curves of waves. Its name 'Sinusoidal' is derived from this fact. The projection is, however, popularly known as Sanson-Flamsteed Projection after the name of its author, Sanson, a French Cartographer, and Flamsteed, the British Astronomer Royal, who used this projection very often for his star maps.

This *projection is a Bonne Projection with the equator as the standard parallel.* It was noted in the case of the Bonne projection that the curvature of the

parallels was determined by the standard parallel. In this projection the standard parallel, the equator, being a straight line all other parallels are, therefore, straight lines. The meridians, however, as in the case of the Bonne Projection are curves. It is, therefore, not correct to say that it is a 'modified form' of the Bonne projection.

With the difference of the parallels, as noted above, all the properties of this projection are those mentioned in connection with the Bonne Projection.

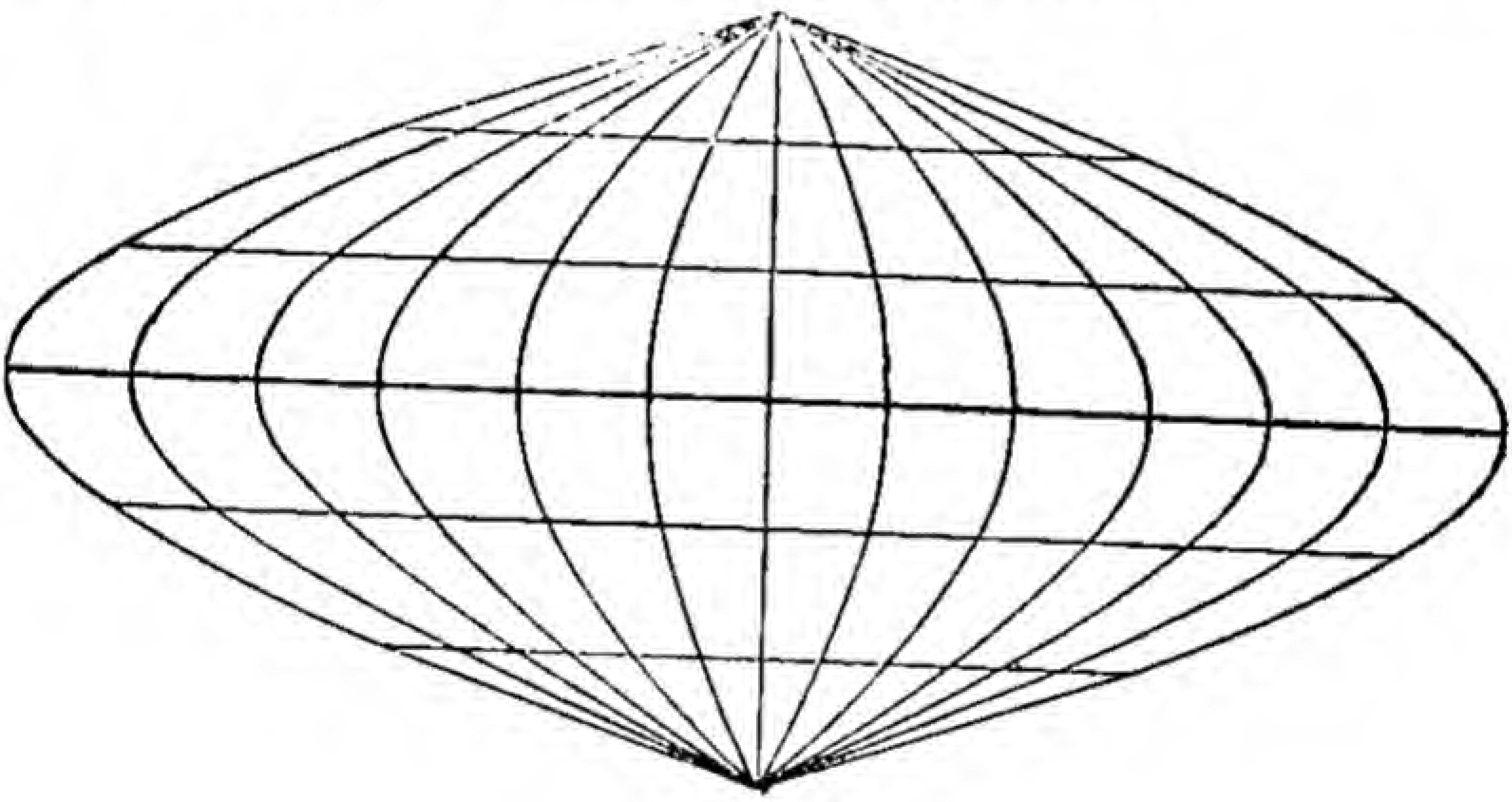


Fig. 49

The construction is also similar. The only point of importance is that the central meridian here is half the length of the equator. The central meridian and the equator are divided true to scale by the length of the arc for the interval in degrees at which the parallels are to be drawn. The parallels are divided true to scale according to the method shown in the case of Bonne Projection.

The Sanson-Flamsteed Projection is best suited for

areas near the equator, provided they do not have a very great north-south or east-west extent. Thus, Africa and South America can best be shown on this projection. It is not suited for maps of Asia or Australia, because of their great distance from the equator and a wide east-west stretch.

Polyconic Projection

The Polyconic Projection was devised by an American, Ferdinand Hassler, the first superintendent of the U. S. coast and Geodetic Survey. It is a link between the 'scientific' and the 'conventional' projections. Its principle is based on the assemblage, one over the other, of a number of hollow cones. These cones give the parallels, which have a separate tangent meeting the polar axis. Each parallel has, therefore, a separate centre of its own. The projection as practically used is, however, considerably modified from the above principle by mathematical tables.

The properties of this projection are generally those expected in a conical projection. These properties are:—

(i) The parallels are curves; but unlike other conical projections, they are not concentric.

(ii) The meridians, except the central meridian, are curves, as in Bonne Projection.

(iii) It is neither a conformal nor equal-area projection. Near the central meridian, however, it has the characteristics of both. Within a distance of 560 miles from the central meridian, the error in scale at any point on the map is only about 1%.

(iv) The distortion in scale increases rapidly at the margins of the map.

The construction of this projection is similar partly to the Simple Conical projection and partly to the Bonne projection.

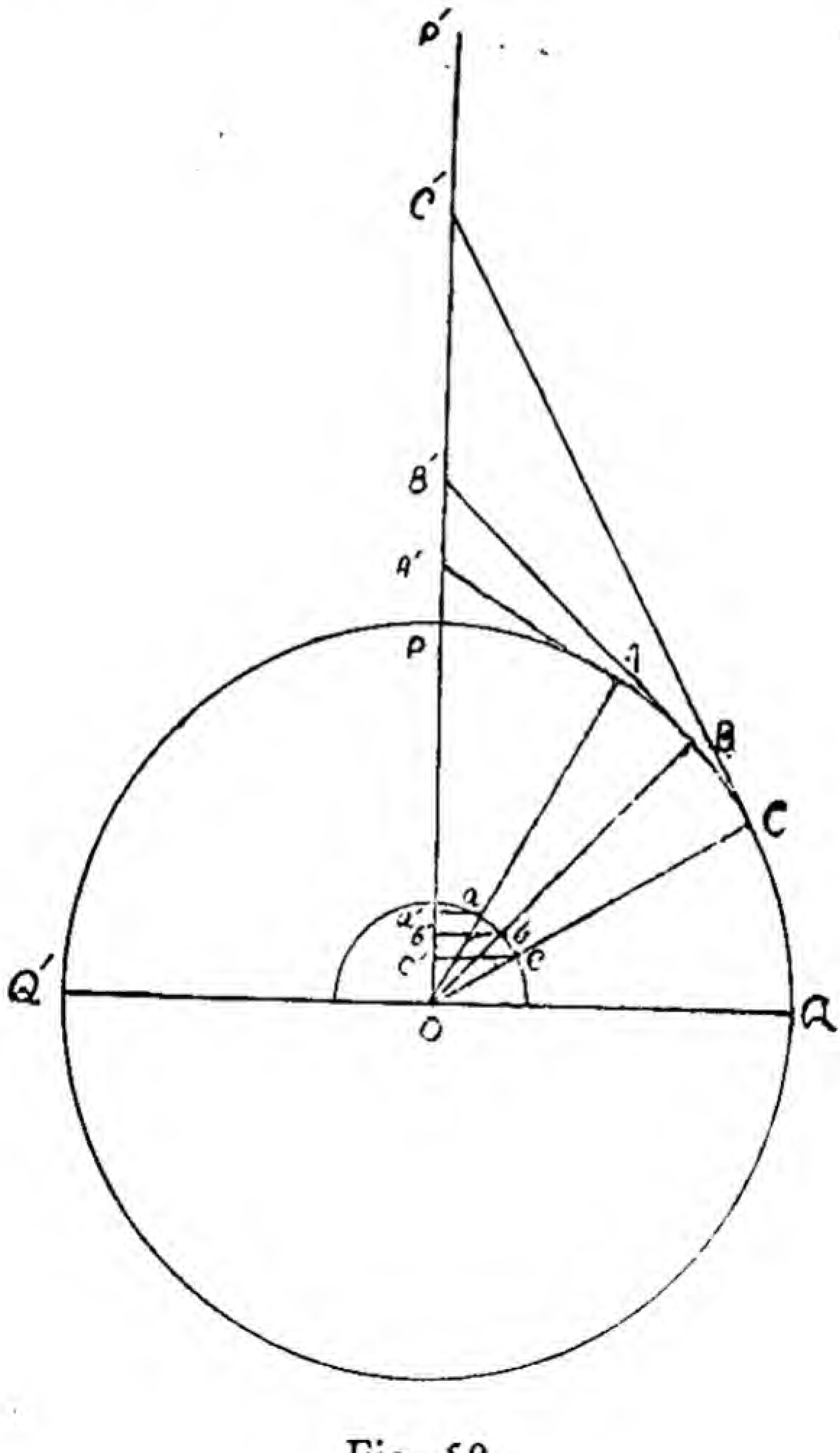


Fig. 50

Describe a circle (Fig. 50) on the selected scale. Proceed as in the case of the conical projections, described above, to get the measurements for dividing the central meridian and the parallels. Draw tangents from the points representing the various parallels on the circle to meet the polar axis produced to get the radii of the parallels.

Then draw the projection, as shown in Fig. 51, by having the central meridian OP′ and dividing

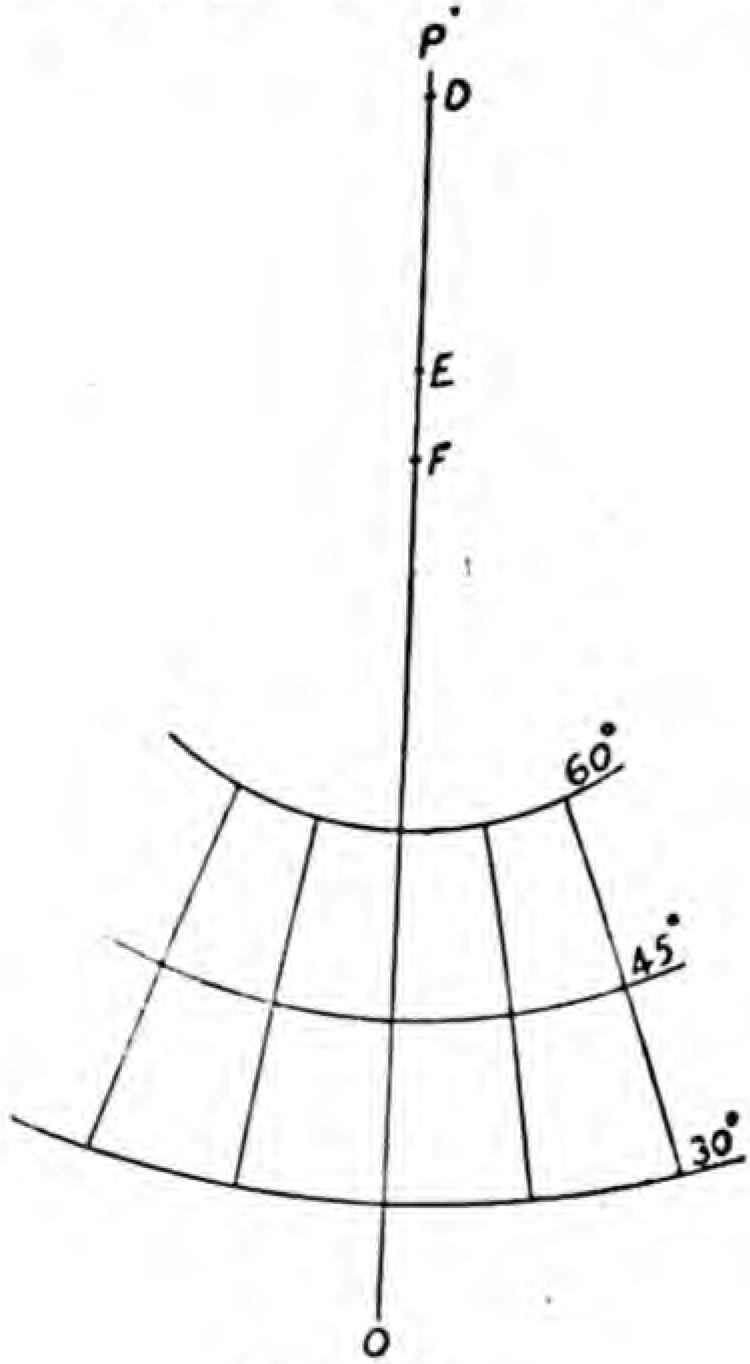


Fig. 51

it by the distance CQ on the circle. Through the points of division so obtained draw curves, to represent the parallels, with D, E, and F on the

central meridian as centres and AA′, BB′ and CC′ as radii. For determining the position of D, E, and F, it is convenient to take the length of the radius of the parallel on the compass. Place one leg of the compass on the point of division on the central meridian representing the intersection of the parallel and then note how far the other leg goes towards P′. Fix the metal leg there and draw the curve through the division point with the pencil leg.

Then, divide the curves representing the parallels of 60°, 45° and 30° on the projection by aa′, bb′ and cc′ respectively. Join the points of division by curves to show the meridians.

The chief use of this projection is to make maps of small areas necessitated by topographical surveys. The greatest advantage of this projection for this purpose lies in the fact that separate sheets may be plotted independently, with the help of tables. A large number of these sheets can be joined together afterwards, thus giving a map of a large area without much error. For each sheet thus plotted the scale error is only about 1/1300. The ease of construction is another advantage of this projection.

There is, however, a limit to the number of sheets that can be joined together. It is to be noted that only those sheets can be joined together which have the same central meridian. In other words, the east-west joining of the sheets is not perfect. Ordinarily, more than nine neighbouring sheets cannot be joined together satisfactorily. This is shown below:—

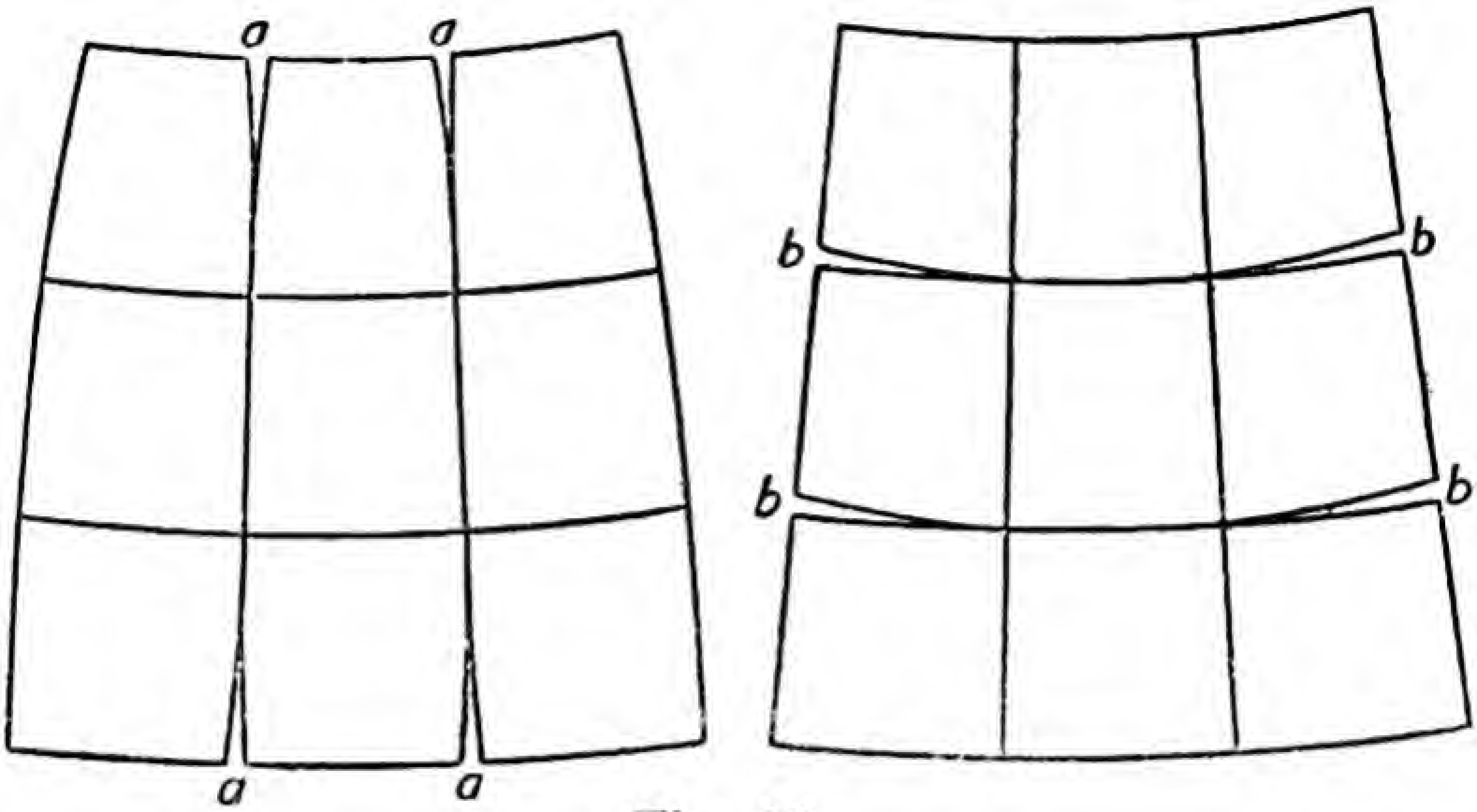


Fig. 52

The projection is not suited for large areas if the longitudinal extent is great. In fact, this projection is good only for *wide latitudinal* and *narrow longitudinal* extent.

The importance of the Polyconic Projection is enhanced by the fact that a modified form of it has been selected for drawing the International Map of the World. The modification has been devised by Lallemand.

In this modification the top and bottom parallels of each sheet are drawn from tables, but they are *not concentric.* These two parallels are then divided true to scale, as in the Polyconic Projection. The points of division are connected by *straight lines* which represent the meridians. Another modification is that the central meridian is not divided true to scale, but it is the two meridians 2° to the east and 2° to the west of the central meridian of each sheet that are divided truly. The scale along the central meridian is, therefore, slightly

reduced. But by dividing two meridians true to scale on each sheet the modification distributes the scale error.

The chief advantages of the modified form of the Polyconic Projection, therefore, are:—

(*a*) the fitting together of a number of adjoining sheets, owing to having straight meridians;

(*b*) distribution of scale error, owing to having two meridians divided truly.

Cylindrical Projections

The cylindrical projections are similar to the conical projections in that the basis of projection is the same; the globe being projected on a developable surface. As in the case of the conical projections, the cylindrical projections are also considerably modified by mathematical tables before being used. There are a number of projections in this class, but, with one exception, they are seldom used. This exception is the Mercator's Projection.

Mercator Projection

The Mercator Projection derives its name from the assumed name of Gerhard Kraemer, a Flemish cartographer. The projection, as in use today, is however, the result of the modification by Edward Wright of the University of Cambridge. This projection is of great practical value in navigation, because the bearing or direction to be followed by the ships between any two points can be shown on this projection simply by drawing a straight line connecting those points. This line

of bearing, or the Rhumb line* or loxodrome can be easily followed by the ship with the help of the compass. It is this property of the Mercator projection which is responsible for its great popularity.

The properties of this projection are:—

(i) The meridians and the parallels are shown by parallel straight lines, cutting each other at right angles.

(ii) The equator is shown as a straight line drawn true to scale.

(iii) The meridians are spaced *equally*.

(iv) The parallels are spaced *unequally*, with a view to balance the distortion brought about by having straight meridians instead of curves as on a globe.

(v) All bearings or loxodromes on this projection are shown by straight lines. This is due to the combination of the following two features:—

(*a*) Balancing of scale both along the meridians and the parallels, and

(*b*) The meridians and the parallels cut at right angles.

(vi) The projection is conformal, and, therefore, the shapes on the map are correct. In higher latitudes, however, where the exaggeration in scale is considerable, the shapes are greatly *magnified* though not distorted. It must be noted that conformality in this projection applies only to points and not

*Rhumb is an old word meaning Compass direction.

to large areas, for the scale changes constantly.

(vii) Areas are not correctly shown on this projection owing to the constantly changing scale. Along the equator, which is truly represented, however, both areas and shapes are correct.

(viii) The polar areas are greatly distorted, as the pole is shown by a straight line equal to the equator and not by a point as on the globe. Owing to the marked exaggeration of scale near the poles, this projection seldom extends beyond 85°, North or South of the equator. An idea of the exaggeration of the scale in the higher latitudes can be had by the fact that the areas are magnified about fifteen times on the 75th and about thirty-three times on the 80th parallel. It is on account of this exaggeration that on this projection Greenland appears to be greater than South America, though actually it is only about one-ninth.

(ix) The cardinal points, (north, south, east and west), always point the same way and remain parallel to the borders of the map. This property is of great import for meteorological charts.

This projection is constructed with the help of a table and is, therefore, simple. Draw a straight line EQ (3 inches long) to represent the equator on the scale selected. Divide EQ into twelve equal parts to show the meridian interval of 30° (any other interval may

be selected). Draw PP′ at right angles to EQ to represent the central meridian. Divide the central meridian according to the table given (column 3). Through the

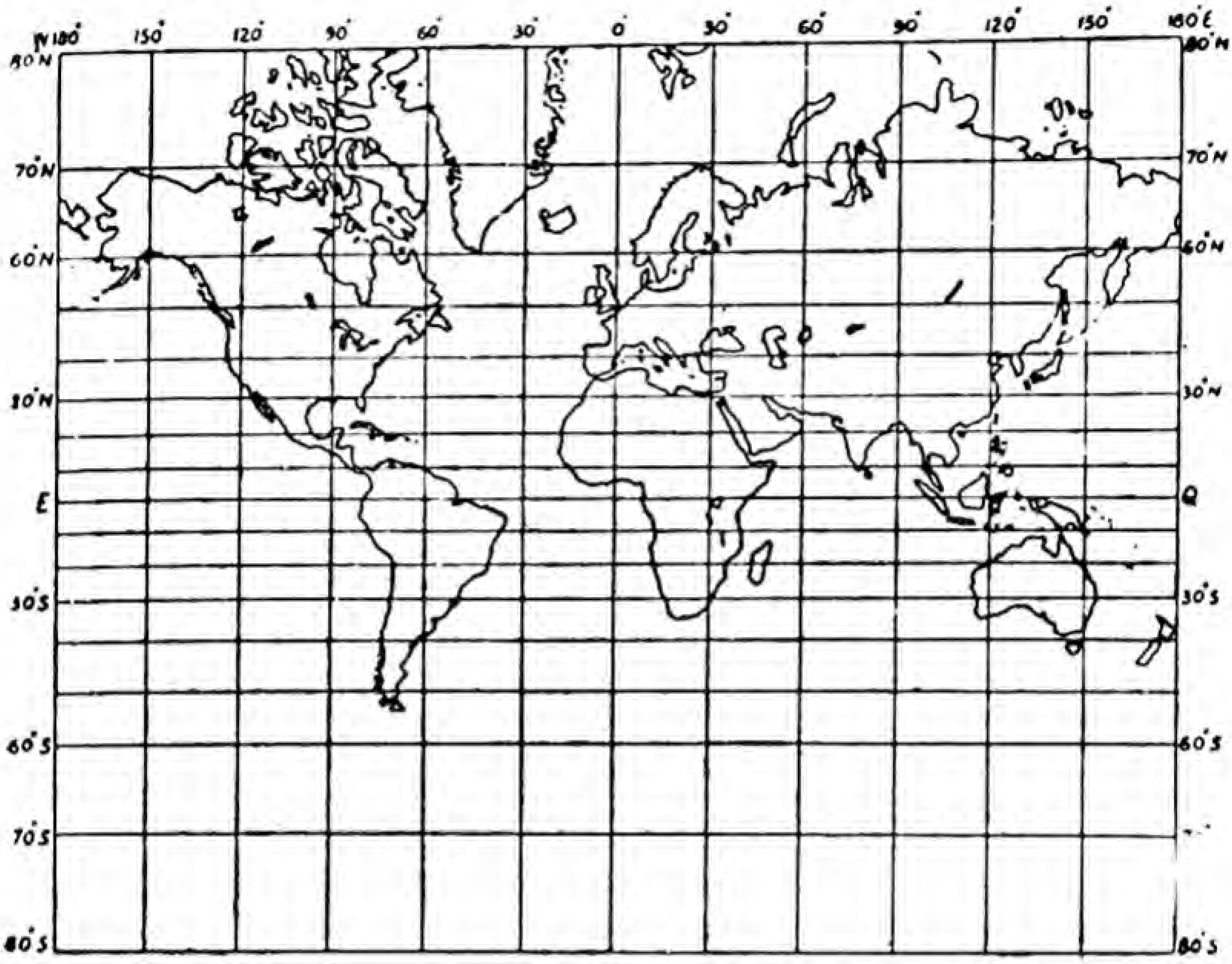


Fig. 53

points of division on the central meridian draw parallels equal to the equator. Then, through the divisions on the equator draw straight lines at right angles to it to represent the meridians. The network of the projection is thus complete.

The distances for 10° intervals can be calculated from the following table by multiplying the radius:—

Degrees Latitude	Distances	Distances when R is 1·5″
10°	·17×R	·25″
20°	·35×R	·5″
30°	·54×R	·8″
40°	·76×R	1·1″
50°	1·01×R	1·5″
60°	1·31×R	1·9″
70°	1·73×R	2·6″
80°	2·43×R	3·6″
85°	3·13×R	4·7″

(From Garnett: A Little Book on Map Projections, page 65.)

The chief use of this projection is for making sailing charts.

The world maps in atlases and wall maps are also made on this projection. The maps showing directions of winds, ocean currents, and sailing routes are all prepared on it.

The Mercator Projection has also been used for making a Hydrographic Map of the World (in 24 sheets) on the recommendation of the committee responsible for the mapping of the ocean bed.

This projection cannot be used for comparison of areas or measurement of distances, except along the equator.

Conventional Projections

There are a large number of projections that produce a satisfactory network of meridians and parallels entirely by analytical methods rather than by removing the defects of the so-called 'shadow projections'. The Mollweide and the Lambert projections are the most popular of such projections. The construction of these projections is done by the help of tables.

Mollweide Projection

This projection owes its name to its author, Karl B. Mollweide, a German cartographer. There are other names in use for this projection also; as the 'Homolographic projection' or the 'Elliptical projection'. The popularity of this projection is mainly due to its equal-area character. This projection can be easily recognised by its elliptical boundary.

The properties of this projection are:—

(i) All the parallels are straight lines and are *unequally spaced*.

(ii) All the meridians, except two, are ellipses.

(iii) The central meridian is a straight line and is only half the length of the equator. The meridian of 90° is a circle and bounds the hemisphere.

(iv) The equator is divided true to scale where alone on this projection the scale is true. The scale is exaggerated along the parallels and somewhat reduced along the meridians in the higher latitudes.

(v) The parallels are not true to scale. Those

near the equator are a little smaller, while those near the poles are a little larger than they are on the globe. This, however, makes up the variation caused in the width between any two parallels. The projection, therefore, becomes an equal-area projection.

(vi) The distortion at the margins is considerable, but it is less than in the Sanson-Flamsteed projection.

(vii) There is a great distortion in shape, especially in the equatorial and in the polar regions. This is the greatest defect of this projection.

The construction of the Mollweide projection is rather difficult, owing to drawing of ellipses. The method is shown in the following diagram:—

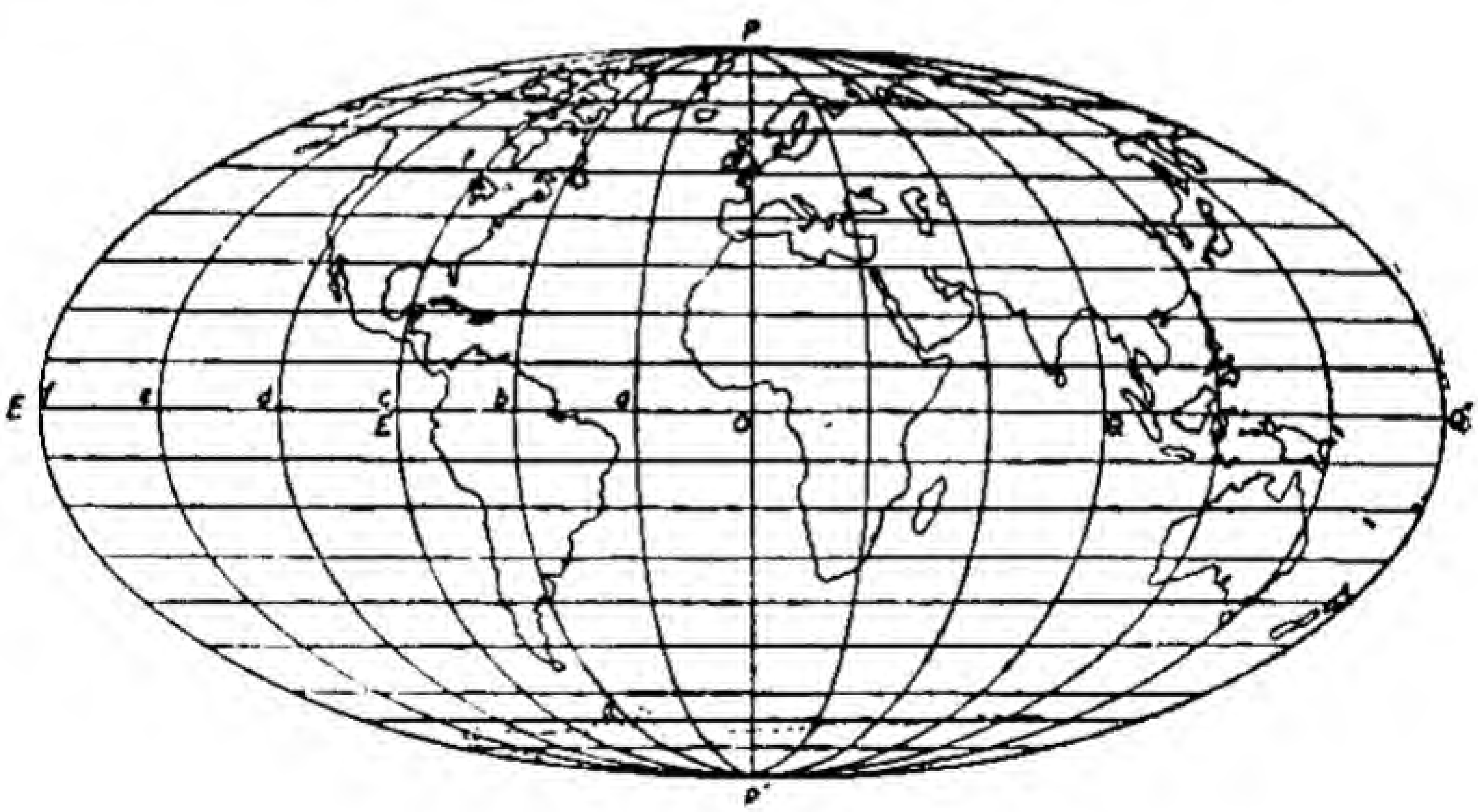


Fig. 54

Draw a circle EPQP′ with O as the centre, and *half* the length of the radius given by the scale selected,

as radius. The circle so drawn represents the 90th meridian and encloses the hemisphere. Draw the diameter EQ of this circle. Produce it on both sides to Q′ and E′, taking care to make QQ′ and EE′ equal to QQ. Then E′Q′ is the equator. Also draw the polar axis PP′ to represent the central meridian.

Mark on this circle the points where the various latitudes will intersect it, according to the angular measurements given in the table below.

Through these points of intersection draw parallels to the equator to represent the lines of latitude. Extend these lines beyond the circle on both sides in such a way that the length outside the circle will be equal to the length inside the circle.

Through the outer ends of these lines representing latitudes draw the bounding ellipse. This ellipse is the 180° meridian.

Now, divide the equator and all other parallels to it into the desired number of equal parts for drawing the meridians. Through the corresponding points of division draw elliptic curves to represent meridians.

This completes the projection.

The chief use of this projection is for drawing maps showing distributions which require equal-area projection for purposes of comparison.

This projection is not popular in the United States of America, as this country lies on the margins of the projection and is, therefore, greatly distorted in shape when the Greenwich meridian is taken as the central meridian. When any other meridian suitable for showing the United States of America is taken as the central meridian, Europe is greatly distorted.

The following table gives the angular measurements from the equator for finding out the points of intersection on the hemispherical circle:—

Latitudes	Angular Distance
10°	8°
20°	15·8°
30°	23·8°
40°	32°
50°	40·5°
60°	49·5°
70°	59·5°
80°	71°

Through the points thus obtained on the circumference, parallels to the equator are drawn. Points for drawing these parallels may also be obtained by dividing the polar axis of the hemispherical circle according to the following table:—

Latitudes	Distances from the equator
10°	·13×Radius
20°	·27× ,,
30°	·40× ,,
40°	·53× ,,
50°	·65× ,,
60°	·76× ,,
70°	·86× ,,
80°	·94× ,,
90°	1·00× ,,

Summary of Projections

Projection	Properties	Use
Gnomonic	(*i*) All great circles showing shortest distance are straight lines. (*ii*) Directions from centre are correct. (*iii*) Straight meridians and circular parallels. (*iv*) Exaggeration of scale towards margins, causing distortion there in shape, distances and areas. (*v*) Full hemisphere not practicable on it. (*vi*) Construction difficult, except for polar areas.	Supplementary sailing charts for Mercator. Plans of harbours. Not used for areas more than 30° distant from the centre.
Simple conical (one standard parallel).	(*i*) Straight meridians. (*ii*) Concentric curves for parallels. (*iii*) Scale true only along standard parallel. (*iv*) Neither equal-area nor conformal.	For small areas in middle latitudes, like Denmark, Poland and Ireland.

Projection	Properties	Use
Simple conical (two standard parallels)	Same as above.	For large areas with greater latitudinal extent.
Bonne	(*i*) Fixed straight central meridian. (*ii*) Parallels equidistant concentric curves. (*iii*) Curved meridians. (*iv*) Equal-area but not conformal. (*v*) Exaggeration on margins.	Survey maps in Holland and Belgium etc. Good for any extent of longitude and therefore for trans-continental railways. For large but compact areas; Europe, Australia etc.
Sanson-Flamsteed	Same as Bonne.	Best for areas near equator; Africa or South America.
Polyconic	(*i*) Parallels are non-concentric curves. (*ii*) Meridians curved, except the central. (*iii*) Small scale error near central meridian. (*iv*) Neither conformal nor equal-area. (*v*) Its modification for 1/M map has straight meridians.	For survey maps when modified. The International Map on its modification.

Mercator	(*i*) Parallels and meridians straight; parallels equal in length to equator. (*ii*) Meridians spaced equally, but parallels spaced unequally. (*iii*) All bearings shown by straight lines. This is the best advantage. (*iv*) Conformal projection for points. (*v*) Areas greatly exaggerated. (*vi*) Pole shown by a straight line instead of a point. (*vii*) Cardinal points point the same way.	Sailing charts. World maps in atlases. Routes, direction of winds or ocean currents. Climatic maps generally. Also Hydrographic Map of World.
Mollweide	(*i*) Straight parallels, placed unequally. (*ii*) Elliptic meridians, except central and 90th. (*iii*) Equator divided truly. (*iv*) Distortion in shape. (*v*) Equal-area projection.	Distribution maps, especially World maps. Not popular in U. S. A.

Exercises

1. What are map-projections? Why are they necessary?
2. Write short notes on:—

   (*a*) Equal-area projections, (*b*) Orthomorphic projections, (*c*) Azimuthal projections.

3. Give the properties, construction, and uses of any of the following projections:—

   (*a*) Gnomonic projection;
   (*b*) Simple conical with two standard parallels;
   (*c*) Bonne projection;
   (*d*) Polyconic projection;
   (*e*) Sanson-Flamsteed projection;
   (*f*) Mercator projection;
   (*g*) Mollweide projection.

4. Give an account of the characteristics, uses and limitations of Mercator's Projection.

5. Construct a simple conical projection on the scale of 1/50,000,000, with the standard parallels of 40°N. and 70°N. and the central meridian of 30°W.

6. Construct a Bonne projection on the scale of 1/160,000,000, selecting 40°N. as the standard parallel and 80°E. as the central meridian.

INDEX

PHYSICAL BASIS OF GEOGRAPHY

R. N. DUBEY, M.A., D.Litt.

Physical Geography forms the basis of every branch of Geography. A clear grasp of the physical basis of Geography is verily the primary requisite of a serious student of the subject. But it is a sad fact to confess that no book on Physical Geography has yet been written by any Indian author. Truly, there are some good English books on the subject but they are vitiated by only a partial treatment of the subject, besides being rendered less useful due to their foreign authorship which makes the illustrative and textual matter difficult for an Indian reader to understand and go deep into. Dr R. N. Dubey, who is specially qualified for such a task, has, therefore, written the present book and thus sought to remove a long-felt want of Indian students.

This book has numerous attractive features which prompt us to recommend it very strongly to our clientele. It is specially suited to Inter. and B.A. students who have to consult a large number of books for gathering all the material, a task which they can only ill-perform due to want of time, capacity and books. Most recent articles and books of English, American, French, German and Russian geographers have been consulted, most of which have not even been translated into English. He has given an entirely new orientation to the whole subject, which is at once refreshing and lucid, simple and fascinating. The utility of the book has been heightened by the fact that Indian examples have been used as far as possible along with typical examples wherever useful, which makes it an interesting reading for an Indian student. The book has been richly illustrated with maps and sketches.

Price Rs. 6

ECONOMIC AND COMMERCIAL GEOGRAPHY

R. N. DUBEY, M.A., D.LITT.

The aim of this book is to provide a comprehensive and clear-headed treatment of the principles of Economic Geography and a description of the objective geographical conditions of economic interest obtaining in the world today. The wheels of time, in all political, economic and ideological spheres are moving so rapidly that the secular reflex of the kaleidoscopic changes leaves the principles of economic geography, and its basic objective data, drastically turned and twisted. This makes the task of a geographer one of extreme difficulty and heavy responsibility—a task which can be faithfully discharged only by really capable hands who keep abreast of all modern developments and can make necessary changes in the time-honoured principles, that the march of time dictates. The present book is an attempt in this direction. The material for this book has been painfully collected from various economic and geographical journals, recent authoritative works on the subject in English, French, German languages, the class-rooms of European Universities and the personal observations of the author. Clear thinking, lucid treatment, up-to-date statistics, plenty of maps and diagrams and above all an attractive get-up, are some of the features of the book. It has been recommended by many Boards and Universities for I. Com., B. Com., I.A., B.A. (Geog.) and M.A. (Econ. & Geog.) Classes.

Price Rs. 4

ECONOMIC GEOGRAPHY OF INDIA

R. N. DUBEY, M.A., D.Litt.

The present book removes a significant and long-felt lacuna in economic and geographic literature on India. At present there is hardly any good book written by an Indian on this subject. If an economist has taken the work in his hands he has allowed economic aspects to overshadow and eclipse the geographic ones. If a geographer has made an attempt he has produced something which is mainly physical and political rather than economic. Thus Indian economic geography has been choked up by either economics or geography. The present work is written by a writer who is both an economist and a distinguished geographer of standing extending over a decade and a half. He has scrupulously chalked out the proper domain of the subject and gingerly kept apart the intrusive elements.

This book is characterised by simple language, lucid treatment, up-to-date statistics, incorporation of recent geographic researches in Europe, America and India and above all, a broad national point of view. It is liberally equipped with original sketches and maps which are entirely new things to teachers and students of the subject.

A new, original and authoritative work as it is, it will be a first-rate equipment of undoubted value to libraries.

Price Rs. 3-12

"This book was taken from the Library on the date last stamped. A fine of ½ anna will be charged for each day the book is kept over due."